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". . . More Valuable and Interesting; Less Stupid and Dull . . ."

By C. J. FREUND

Vice President, A.S.E.E.

"How did you like the program of conferences at Minneapolis? How do you think the conferences can be improved? We did think that the conferences at the University of Minnesota were pretty good, but how can they be made better at Austin next June?"

That, or its equivalent, is what we wrote to the chairmen of the Society's divisions and committees right after the Minneapolis meeting. The chairmen poured in a flood of suggestions, for which we thank them most heartily. Many of the returns expressed more or less isolated opinions of the individual chairmen, or viewpoints of their associates in the respective divisions and committees, but a number of points were so repeatedly mentioned as to prove a clear consensus of opinion. The divisions and committees apparently agree that:

(*a*) Final programs should be in the hands of the Society's members before they leave their homes for the annual meeting.

(*b*) The schedule of general sessions and conferences should be uniform from day to day throughout the meeting.

(*c*) Invited speakers should be informed long in advance of the meeting, on which day, at what hour and in which room they are to appear.

(*d*) Conferences should be evenly distributed over the half days and evenings of the meeting; if the conferences are largely concentrated within a day, or a day and a half, too many conflicts result.

The Executive Board of the Society met at Pittsburgh on August first and thoroughly went over these suggestions. In order to accomplish the improvements which the chairmen of the divisions and committees had in mind, the Executive Board determined that:

(*a*) General sessions will be held in the morning only, leaving afternoons and evenings for the conferences of divisions and committees.

(*b*) Each division and committee shall schedule no more than two conferences, in addition to luncheon and dinner sessions.

(*c*) The General Conference Committee of the Society shall assign days, hours and rooms for the conferences, luncheons and dinners of the divisions and committees.

(*d*) The Engineering College Administrative Council and the Engineering College Research Council shall each be assigned one general session of the Society and, in addition, shall hold one or two conferences, and luncheons and dinners as the Coun-

cils may elect. The General Conference Committee shall assign days, hours and rooms for conferences, luncheons and dinners; arrangements for general sessions shall be made with the Society's Program Committee.

(*e*) The preliminary program for the Austin meeting will go to press on February first, 1948; the final program will go to press on April 24.

Thus, the Executive Board established a new order for the annual meeting. At first sight these new procedures may appear rigid and drastic. In the long run, they will certainly be conducive to a type of annual meeting which the members of the Society will find very much to their liking.

An important effect of the change is that program making cannot wait until late in April as in other years; the first printing of the program will be issued nearly three months earlier than that.

May we respectfully suggest to the chairmen of divisions and committees that they BEGIN IMMEDIATELY TO PREPARE THEIR CONFERENCE PROGRAMS. Otherwise they will do a rush job under pressure of a deadline, and a conference hastily prepared is likely to be the kind of conference which sends the members of the Society out of doors to take their ease in the shade of campus trees.

The divisions and committees have earned for the Society a gilt edged reputation for stimulating conferences. Members will agree that more of the Society's conferences have been valuable and interesting, and less have been stupid and dull, than in most organizations to which they belong. This reputation must by all means be sustained and expanded.

But the matter of immediate concern for all of us is an EARLY START. It takes at least a month to work up a good conference program; and February first will turn up on the calendar before we are ready for it.

In a week or two we shall begin writing to chairmen of divisions and committees for program data.

And so, now, all together!

Tomorrow's Engineers*

A Reconnaissance Survey

By J. R. VAN PELT

Battelle Memorial Institute

As you know, the announced title of this talk is "Tomorrow's Engineers." You will be right if you infer that I intend to discuss with you the future of engineering as a profession. The discussion will, of necessity, be only a reconnaissance survey; but even a reconnaissance may be enough to give us a good idea of the general location of our future right-of-way.

You should be warned at once, however, that this paper reveals no occult knowledge of what is in store for the profession of engineering. The road ahead, as I shall describe it, may be scanned by any of us who will take the trouble; undoubtedly it is familiar territory to many of you. The prediction of our future course is, therefore, not the main point of this paper. It is only an introduction—a groundwork preceding certain conclusions and recommendations which may affect the program of this Federation and its member societies.

You should also be warned that I am not a reformer. I offer no miraculous panacea for the ills of the profession. It seems to me that what our profession needs is not revolution, but the sincere attention and devoted cooperation of all qualified engineers.

Indeed, I am not so sure that the profession has any very serious diseases. It is young, and may suffer growing pains. It may show the unpredictable awkwardness of a lanky adolescent. It certainly has its annoying ailments. But none of these, it seems to me, should be dignified with the term "disease." On the contrary, if we judge the profession by its results, which after all are the only measure that means much, we have every reason to be proud. What other profession can match it, in reliability of its services, or in rate of improvement? The engineering profession has done a great job of translating the discoveries of science into the useful tools which have lightened man's physical burdens, improved his health and prolonged his life, speeded communication and pushed back frontiers, so that we may hope to arrive at a world-wide culture and civilization in only a fraction of the time which our grandfathers would have thought possible. The engineer has not done these things unaided, but he has been an essential element—probably the dominant element —in this great drama of man's material progress in the western world.

Even in the darkest hour of a technological war, when the power of engineering was focussed on human destruction, engineers had faith to look

*An address before the Minnesota Federation of Engineering Societies, Minneapolis, February 27, 1947.

ahead to a distant and brighter day: to see that our conquest of nature, though temporarily applied to warfare, holds for greater values in peace. We see that engineering, by means of the wealth and leisure which it creates, can free the mind as well as the hand; that it gives to the public at large the opportunity to acquire an education, and the time to cultivate those things of the spirit which alone can change the world from a perpetually armed camp into a friendly, prosperous, and progressive neighborhood. No profession has bestowed on mankind more potent opportunities for human betterment.

How has the profession of engineering been able to achieve these great results? Certainly not by adopting an attitude of easy self-satisfaction. Probably no profession has been less given to the insidious vice of complacency. It has always been marked by healthy dissatisfaction with its past, and an amazing readiness to discard a good technique in favor of a better one. Some years ago the production engineers of a Chicago newspaper scrapped a battery of nearly new presses in the pink of condition, merely because they were too slow. Each of these machines could turn out the amazing number of 33,000 complete newspapers per hour, but the publisher would not give them floor space because other presses had become available, through research and engineering, which could turn out more than 50,000 papers per hour. Similarly, in the aircraft industry it is a commonplace that every new airplane design is obsolete before it is off the drawing board. In our profession which so cheerfully discards the good for the better, it is only natural that we should look eagerly to the future betterment of the profession itself without implying any criticism of the past.

The Road Ahead

Let us, then,

> ". . . dip into the future
> Far as human eye can see. . . ."

which, after all, may not be very far, and try to discern the broad movements which are affecting and will continue to affect the engineering profession. In this admittedly difficult endeavor, it would be futile to concern ourselves with details. The broader the trend, the greater its significance; and the more worthy of our careful study.

Following this plan, then, I think we can single out two great movements which characterize the American scene today, and consider their impact on the engineering profession. We shall do this with the full realization that such reconnaissance mapping leaves much detailed contouring to be done. We may be reasonably sure, however, that within the limits of error which we set up for ourselves, we can map the major features of the territory correctly.

The first of these major features is the trend toward a larger and larger element of science in industry, and hence in engineering; and the second relates to the human and social factors in industry. The one deals with the laws of nature, the other with the individual and society. They are thus at opposite poles of the engineer's world, yet before we conclude we may find a significant element in common between them.

Science in Engineering

The growing importance of science and mathematics in engineering is by no means a new idea. For at least a generation that unfortunate character the "handbook engineer," has been the laughing-stock of the profession. As a

student he wanted a "practical" education, and dodged mathematics, physics, and chemistry as much as he could. As a practicing engineer he is lost without his well-worn handbook, because he does not know any fundamental principles. Confront him with a problem not in the handbook, and he's helpless.

There is little room for such "engineers" in the newer, more highly scientific fields of engineering like electronics, physical metallurgy, and aeronautics, in which science and engineering are close partners. In the aircraft industry, for example, side by side with the growth of applied aeronautical engineering, investigations of a more fundamental nature have been necessary in the dynamics of fluids, in surface effects, in airfoil sections, and in the principles of structural design. In this relatively young branch of engineering, basic and applied science are constantly working hand in hand. The same is true to a varying degree throughout the profession, but especially in those industries which are marked by high rates of obsolescence and innovation. A general rule might be stated thus: the closer the cooperation between science and engineering, the more rapidly will the industry advance.

This close connection is not, however, to be thought of as a one-way street in which all the original work is done by the basic scientist and the engineer merely borrows these fundamental discoveries and turns them into gadgets. There is, to be sure, a certain element of truth in this view, as exemplified by a remark that Kettering credits to the Nobel prize winner in physics, Harold C. Urey. When asked what is the difference between science and engineering, Dr. Urey is supposed to have replied, "About twenty years." The implication is that after the scientists have discovered or created all the necessary basic elements of a new device or industry, engineers spend a few years cobbling them together into a useful and salable device, using no more ingenuity than is necessary to develop a workable manufacturing process. It is true that the useful application of science is the province of the engineer, that through the engineer's efforts the laboratory curiosity of today becomes the tool of industry tomorrow; but in fast-moving technological industry, the engineer is much more than a mere borrower from science. The true relationship of the engineer and the scientist may be described as a cross-fertilization of ideas, each profession contributing something which assists the other to take the next step in its own field.

Nowhere is this teamwork of basic and applied science more conspicuous than in the rapidly growing field of industrial research. The leaders of our great technological industries are well aware of their dependence on both basic and applied science, and in their laboratories they support both kinds of research. Here scientists rub shoulders with engineers, they work together on the same projects, and thus reduce or eliminate the traditional gap between theory and practice. The familiar terms "industrial chemist," "engineering physicist," and "industrial physicist" highlight the importance of basic science as a factor in engineering and industry.

In the interval between the First and Second World Wars, applied research experienced a ten-fold expansion, involving an outlay in 1941, of some $300,000,000. During the late war, as might be expected, the figure went up to the neighborhood of a billion dollars

a year, which put research in the category of a major industry. Surveys of future trends in research indicate a tremendous demand for research services on the part of industry, which may offset most or all of the expected shrinkage in research expenditures by the Government. It is clear that the growing emphasis on basic science in the training of engineers is a step in the right direction.

Though I have emphasized engineers in research, it would be wrong to assume that they are the only ones who profit by a thorough scientific foundation. Many an engineer whose life is spent in production or distribution finds himself in constant touch with science and research; and this promises to be even more usual in the future. The sales engineer, the design engineer, the factory manager, the general manager, all have a heavy stake in the success of the research department, and hence should know and appreciate the scientific basis of research. The headlong growth of technology, its increasing complexity, can mean only one thing for tomorrow's engineers—a demand for engineers trained with a strong flavor of science, combined, of course, with the practicality which is the engineer's own mark.

The Human Element in Engineering

We now come to the second of the great trends affecting industry and engineering—those human elements which are so unlike the emphasis on science which we have been discussing. The engineer has always been concerned with certain matters of human welfare, specifically those involving technology. Many examples could be cited—industrial health and safety, the productivity of labor, traffic engineering, noise abatement, the control of air and stream pollution, the modernization of building codes, the treatment and disposal of industrial wastes, city and regional planning—all these and many more are problems of human welfare in which the engineer is vitally concerned.

If I foresee with reasonable accuracy the long-time trend of our American social philosophy, the engineer will be increasingly concerned with such human problems. This will be especially true of the engineer who enters management. Since management is the goal of a large number of engineers, it is reasonable to say that the engineer's training, either in college or later, should put him in touch with the great social problems which are the concern of management. Three groups of these management problems will serve to illustrate the point. There is the group known as industrial relations—the relation of industry to its own personnel. In this field the manager-engineer is concerned with wage scales and the methods of computing wages; with working hours; with pension systems; with employee insurance; with collective bargaining; and with the intangibles that can make or break the cordiality of relations between workers and management.

In the second group are the problems of public relations, which deal with the attitude of industry toward the public at large and, conversely, of the public toward the industry. Publicity and advertising are always included here, and sales promotion may be; but in its broader aspects, public relations goes far beyond these. Its purpose is to bring the industry into harmony with public opinion, which is the only sound basis for long-range success.

The third of these categories of man-

agement responsibilities is the over-all concern which management must have toward the present and future of the social environment in which the industry exists. The manager-engineer must, for example, have an eye for changing markets, and for the psychology of buyers and users of his product or service. He must take the long view of raw material supply; he must foresee changes in the thinking of investors and of labor. He must have a feeling for the evolution of governmental philosophy, which is reflected in industrial legislation of all kinds, including taxes.

In the more technological branches of industry, all these social problems take on engineering aspects which can be solved by management only with the aid of engineers. This is one of the reasons why so many engineers have been drawn into general managerial positions, and it is the reason why every engineer who aspires to managerial rank should study these social problems.

As a matter of fact, the employment of engineers as general managers is under fire today in some quarters, because so many otherwise excellent men lack, or are believed to lack, an interest in and training for the solution of human problems in industry. It was Pendleton Dudley, President of the National Association of Public Relations Counsel, who recently pointed out that our great industries, in the last half or three-quarters of a century, have repeatedly changed their type of management to meet the most pressing need of the time. In the trust-busting era, many lawyers rose to the presidency of big companies. In the periods following financial over-expansion, bankers have gained control. In times of rapid technological progress, engineers have dominated. Today, Dudley sees the dawn of an era of social change, in which the adjustment of corporate policy to new social philosophies, as well as the interpretation of industry to every social group, will take precedence over all other problems of management. He therefore expects the responsibility for general management to be transferred to men skilled in public relations. Certainly it is possible that some leading public relations experts—and I am not talking about press agents, promoters, or advertising men—may be better prepared to establish corporate policies in harmony with public opinion and current social philosophy than most other groups, including engineers.

Dudley may be right about the coming dominance of social problems in industry, but I am convinced that technology will also continue to be a factor of vital importance to management. It follows, then, that the ideal manager for many a company will be the man who is competent both in engineering and in human relations. The conclusion, with respect to the training of tomorrow's engineers, is obvious.

Education and the Practicing Engineer

We are now in a position to summarize the nature of the problem which faces the engineering profession. We have reviewed two major trends affecting the profession—the increasing emphasis on science, as evidenced by the growth of highly technological industry and the spread of research; and the increasing complexity of, and emphasis on, the social and human aspects of industry. To equip engineers to meet these broadening demands is quite obviously a problem in training—a problem in education. And it is largely nontechnical education; it is education

for competence beyond the daily problems of technology.

If education of this kind is to be successful on a large scale, it will require the interest and active support of practicing engineers. The profession is democratically governed, by which I mean that no major program will prosper unless the majority of active engineers believe in it. Education, especially in the learned profession such as engineering, is inherently the responsibility of every practitioner. It was not the medical schools alone which lifted medicine and surgery from the barber shop level to their present eminence; this great advance, mostly in the last half century or so, would have been impossible without the support and prestige of organized medicine which initiated and still maintains a strong control over the education of doctors. It is not suggested that the engineering profession should follow blindly the methods of the medical group with respect to education, but medicine is cited to illustrate the principle that professional education, at its best, is not the responsibility of a few academicians alone, but of the whole profession. As every engineer knows who has kept in close touch with engineering schools, our educational leaders will welcome organized cooperation from the profession as a whole.

What can the practitioners of engineering do to aid in the education of engineers? First of all it is clearly a job for organized groups; only rarely can the individual working alone serve his profession as effectively as he can through his professional societies.

The idea that engineering societies can contribute to education and professional development will be recognized immediately for its complete lack of originality. These objectives are probably written into the articles of incorporation or the constitution of every engineering society in the country. But in most cases, the education thus offered has consisted chiefly of technical papers, which, though obviously important, have little to do with the needs we have been discussing. But a few professional engineering bodies have made the broadest development of engineers their business. One of these is the American Society for Engineering Education, whose membership includes, among others, most teachers of engineering. Another is the National Society of Professional Engineers, with affiliated state associations which act as regional operating units, after the pattern of the American Medical Association. A third is the Engineers' Council for Professional Development. Others, operating usually on a local or regional basis, have also done excellent work in their own territory. There is, therefore, no lack of organizations to which we may turn for action.

A Suggested Program

But precisely what action is needed? In general terms, it seems clear that three types of education, supplementary to those commonly in use, would be of great value to the engineer, and through him to society.

First, we should provide additional means whereby the engineer, throughout his career, can keep up with changing technology and science. Technical books and journals are, of course, available; but there is a real need for organized programs of study under a competent leader—programs designed for the practicing engineer.

Second, we should provide a similar opportunity in nontechnical fields. We should help the practicing engineer to acquire the breadth of background, outside of his immediate profession, which

will enable him to meet with wisdom and understanding the human problems that will confront him as his responsibilities grow.

Third, we should bring engineering home to the public, and particularly to high school seniors, in an interpretive and not a promotional spirit, so that the profession may attract only the ablest recruits.

In order to implement such a program, it seems to me that local and regional engineering societies, or groups of societies federated together, might consider the establishment, as one of their most important subdivisions, of a committee or commission on professional development composed of men who have demonstrated the deepest concern for the profession as a whole and its growth and integrity. Such a commission might include representative young men as well as men of greater maturity; it might cover all major branches of engineering; and might include a reasonable number of engineering educators and research men. The rest of the personnel might be made of practicing engineers—consultants, engineering designers, engineering salesmen, production men, construction men, managers.

It should be the duty of such a group to work out and operate long-range plans for the development of the profession of engineering as a whole, within its territory.

The actual work of such a commission, other than its general planning, presumably would fall upon subcommittees. One subcommittee might be devoted to continued scientific and technical education of engineers after graduation. In cooperation with engineering schools within its territory, its job would be to provide suitable educational opportunities, including "refresher courses" and up-to-the-minute instruction in new theory and practice, for men who have finished their formal schooling. In large industrial centers this might be done through evening classes, and in more scattered localities, through correspondence courses.

A second subcommittee might be devoted to nontechnical education of engineers. Its objective would be to provide the engineer, probably a few years after graduation, with the latest and best information on the human and social side of industry, as well as on the needs of the individual in dealing with his fellow men. Instruction would include such matters as corporation finance, organization of industrial research, patent law, psychology, labor relations, and broader aspects of economic and social philosophy.

The courses thus made available by these two subcommittees would not be offered at random, but would be carefully graded and timed to the three stages of progress of the young engineer—by which I mean:

First—the *technological* stage, when he is still a private in the ranks, taking but not giving orders. Here he needs to know, in addition to his technology, how to get along with his associates.

Second—the *supervisory* stage, when he has a few or many people working under him. At this period he needs to know much about the philosophy of handling men, and the law and public opinion about the relations of employer and employed.

And third—the *policy* stage, when he sits at or near the top, and is looked to for sound judgment and foresight in framing company policy to solve all the puzzles that confront his company in this fast-moving world.

A word of caution: No such educational program should be undertaken with the idea of producing mature engi-

neering executives in ten easy lessons. Engineers are well aware that these skills—at all three stages—can be tempered only in the heat and cold of experience. But the basic data, the organized study of what has been learned from past experience—these are certainly the job of education, and chiefly of postcollegiate, on-the-job education, where formal instruction can be so effectively tested against current experience. The purpose of this proposal, therefore, is to provide machinery whereby formal instruction not available in a four- or five-year engineering course may be made available to engineers at the time in their careers when it will be most useful to them.

A third subcommittee could be charged with responsibility for vocational counseling of high school seniors. It would organize and train counseling teams to reach every high school in its area, so far as that would be possible. It would approach its task not as a selling job, but rather with a view to helping boys to find their proper place in society. Its counseling teams would be armed with the excellent manual prepared by ECPD, and with such books as "Building an Engineering Career" by C. C. Williams. They would emphasize the rigorously high standards which the profession maintains, and they would encourage to join this select profession, only those few high school seniors whose mental capacity, personality traits, and inclinations are in accord with the demands of the highest standards of engineering. This subcommittee, over a period of years, would have the satisfaction of helping to improve the calibre of the young men entering the profession. From personal experience I can testify to the satisfactions thus gained.

Other subcommittees could be organized as the need arose, such as one on standards of professional ethics, or one on public relations of the profession.

It will be seen that this program would benefit greatly by close cooperation with the Engineers' Council for Professional Development, which is organized along closely similar lines. The ECPD has already assisted a number of local groups in forming such committees and I understand is ready to do so on request for any other group. The idea of organizing evening courses and correspondence courses through engineering societies, likewise, is not original with the speaker. It has been done in a number of places, usually on a small scale and designed to satisfy the demand for specific courses, rather than as part of a long-range plan of professional development. John S. Crout of Battelle Memorial Institute has recently suggested a very complete, well-organized plan of the latter kind, in a paper which was presented in March before the AIME in New York. I am especially indebted to him for permission to borrow a part of his plan for inclusion in the present paper.

I see, then, in the years ahead, *no less* need for practical technological training, but in addition to that, a need on the part of engineers for more understanding of science and its methods, closer coordination between research and the other engineering occupations; and especially, I see a need for engineers trained to handle their social responsibilities with skill and statesmanship. I see a need for doing a much better job of interpreting the profession to laymen, chiefly for the purpose of attracting the very finest talent into engineering. And I look to the organized profession to work hand in hand with engineering schools, to provide tomorrow's engineers with the skills to solve tomorrow's problems.

The Mathematical Engineer or the Industrial Mathematician*

By KAJ L. NIELSEN

U. S. Naval Ordnance Plant, Indianapolis, Indiana

1. *Introduction.* It is the purpose of this paper to present a portrait of an individual who must have a high place in our present day design, development, and research engineering. Whether we call this individual a mathematical engineer or an industrial mathematician is quite immaterial. Being a mathematician I prefer to call him a mathematician. Other mathematicians may prefer to call him an engineer or consent to the term "applied mathematician." However, I wish to make a distinction between the mathematician who in his academic university career does research in the so-called field of applied mathematics and the mathematician who seeks a career with an industrial organization; it is of the latter that I wish to speak.

Perhaps it would be best to make a specific definition. I do not propose that this is an all inclusive definition nor even that it is a good one, but it will serve as a basis for argument.

The mathematical engineer or the industrial mathematician is an individual who has been trained in engineering and mathematics through at least a master's degree (preferably a doctorate) and who then assumes a position with an industrial organization and practices the profession for which he has been trained.

The term "industrial organization" shall be used to denote its usual meaning, and governmental agencies engaged in research and/or production, private laboratories and any other organization, company or corporation which conducts design, development, and research engineering or quantity production.

That such an individual already exists and has for some time is, I believe, quite clear to this group and therefore I do not think it worth while to give a historical background as to his evolution. Suffice it to say that the recent military conflict gave greater impetus to the importance of mathematical paper analysis in design, development, and research engineering. However, I hasten to add that the mathematical analysis of this kind was widely used prior to the war and that the war only focused its importance and extended it to wider fields. In support of that statement I refer you to T. C. Fry's article in the *American Mathematical Monthly*† where he discussed indus-

* An address delivered before the annual meeting of the American Society for Engineering Education on June 20, 1947 at Minneapolis, Minn.

The opinions expressed herein are solely those of the author and do not reflect those of the U. S. Navy Dept. in any way.

† T. C. Fry, "Industrial Mathematics," *American Mathematical Monthly*, Vol. 48, No. 6, Part II, Supplement, June–July, 1941.

trial mathematics and which is very good reading.

Having thus defined a highly skilled scientist and assuming that you will agree that he exists, I should like to proceed to a consideration of the two main topics which necessarily are associated with him; namely,

(1) the need for such an individual in our present day scheme of things, and

(2) his background and education.

2. *The Need for the Industrial Mathematician.* I believe that it is quite clear to this group that modern design, development, and research engineering has reached the place where it relies very heavily upon paper analysis before an idea is actually put into physical being. The old concept of taking an inventor's idea and immediately putting it into metal and then testing its practicability is still with us but it must be admitted that it is not as prominent as it once was and certainly is being overshadowed by the paper analysis method, especially by the larger industrial organizations. The savings of time, labor, and expense by this method have been well proved and this is probably its biggest booster. Furthermore, the very important fact that *a paper analysis leads to ideas for inventions and mechanization* cannot be overlooked. However, I hasten to add that a paper analysis does not always furnish the final answer to a design problem; that answer can at times only be achieved after the design has been built and tested; but here again we may find a need for mathematics in the form of an assessment and evaluation of the testing.

It is difficult to say what constitutes a paper analysis; it may take many shapes and forms. However, it may be characterized in the following manner:

(1) A thorough statement of the problems connected with the design or research;

(2) A transformation of the problems into the language of an analysis which can be done on a drafting board or at a desk;

(3) A large number of problems connected with a modern design dissolve themselves into the language of mathematics. These problems can then undergo a mathematical analysis, the results of which will appear in the language of mathematics;

(4) A transformation of the mathematical results into the language of engineering;

(5) Complete the engineering to the stage of blueprints;

(6) Should the finished product undergo extensive testing then there is a further step in the paper analysis; namely, the evaluation of the test.

The mathematical analysis connected with this modern method of handling design problems has reached a high level. In many cases it has reached the level which can very well be classified as research within the field of mathematics itself. It is therefore unreasonable to assume that the mathematical analysis mentioned above can be done by the usual engineering graduate. Nor is it reasonable to say that we must therefore teach more mathematics to all our engineers. As engineers and engineering professors you will agree that the engineer's curriculum is already quite full; some universities have found it necessary to adopt the five year plan. To burden him with more advanced mathematics than he is already receiving will not solve the problem. It is my firm opin-

ion that the solution lies only in further specialization; namely, to train a mathematical engineer who has an engineering background and who majors in mathematics and preferably continues to further his education to the level of a doctorate.

Does this mean that the engineers should be taught less mathematics than they already are? Since they now have a mathematician in their midst, it may seem logical that he will do the mathematics for them and they no longer will have a need for it. However, the answer to that question is an emphatic, NO! If for no other reason (and there are others *), there is still the very difficult task of arriving at a common language between the engineer and the mathematician and this is a very important problem. Each must have some understanding of the other's subject in order that this common language may be reached. This further emphasizes the need for a specialist who has had some training in both; in other words the mathematician must also have some engineering background.

To substantiate my claim that there is a need for this specialist about whom I am speaking, I can, of course, refer to the practice employed by many leading industries today. Mathematicians have been and are being hired by industrial concerns. Aircraft, electrical, communications, and chemical industries, research laboratories, governmental agencies, and plain production companies are finding a wider need for mathematicians. However, the past method of obtaining these mathematicians have not always been satisfactory and have lead to some sad and unreasonable experiences.

As was pointed out by Fry, most of the mathematicians engaged in industry were "pure" mathematicians who had turned to applied mathematics, or engineers recruited from the ranks and taught higher mathematics by industry itself or by self taught methods. This hardly seems the ideal manner in which to approach a profession. Some companies have hired pure mathematicians not really knowing what to expect from them; in turn the employees have not known how they could help the industry and the results have at times been very unsatisfactory to say the least.

The fault has not always been with the individuals hired nor with the industry which hired them. In fact the fault lies with our educational institutions who have not educated individuals to assume such positions nor have they educated industry to the proper use of such a man. The educational problem is therefore two-fold. We must educate the individual and we must educate those who find a need for his services as to his capabilities and what they may expect from him. Let us therefore turn to the education of the industrial mathematician.

3. *The Education of the Industrial Mathematician.* I do not propose to present here a complete solution to this difficult problem. I do not believe that we can at this time definitely outline an exact program for the education of an industrial mathematician. It must necessarily come as an evolution over a period of years. We are, of course, guided to some extent by the experience of some engineering schools who are already emarked upon such a training program. However, I should like

* See, for example, W. L. Ayres, "Interesting the Engineering Student," *American Mathematical Monthly*, Vol. LI, No. 4, April, 1944.

to express a few of my own personal opinions.

Let us first subclassify the industrial mathematician into the following five groups:

1. *Statisticians.*
   Quality control, assessment, probability.
2. *Electrical Mathematician.*
   Instrument design and development, communications.
3. *Mechanical Mathematician.*
   Strength of materials, vibrations, elasticity, and plasticity.
4. *Dynamical Mathematician.*
   Aerodynamics, hydrodynamics.
5. *Chemical Mathematician.*

There may be others or perhaps we can make finer divisions of fields of interest; however, the above five should suffice for this discussion. I wish to exclude the actuary statistician since his profession is well established and has been thoroughly expounded.

Keeping the discussion still in terms of generalities there are two comments that I should like to make. First, I do not believe that taking a graduate who has had his undergraduate training along the lines of pure mathematics and putting him through a graduate school of applied mathematics will develop an industrial mathematician. It will develop an applied research mathematician who can then do applied mathematical research in an academic way, but not an industrial mathematician. In other words, it is essential that the individual have some undergraduate engineering training. The second point is that we must pay some attention to the individual's personality as well as his capabilities. His personality must fit into an industrial organization. The practice of making industrial mathematicians out of mathematics professors has at times lead to serious difficulty because a person who has for some years lived the academic university life could not acclimate himself to the routine and habits of an industrial organization. At times such an individual has become in the eyes of the organization what is termed a "long hair." As a result he did not enjoy his work and it in turn did not assume its rightful importance. As to whether or not you can educate a man's personality I shall not attempt to decide; I leave that question for our educators. Certainly some screening can be done before a life and a reputation is ruined.

In the education proper it is my contention that a doctorate is preferable and in the study leading to this degree he should cover the undergraduate elementary courses in engineering and mathematics. Furthermore, the following basic fields must be covered thoroughly:

Differential Equations;
Numerical and Graphical Methods;
Theory of Functions of Real and Complex Variables;
Operational Calculus; Vector and Tensor Analysis;
Theory of Equations and Matrices;
Mechanics; Dynamics; and Electricity;
Field of Specialization.

Throughout these courses emphasis must be placed on the solution of actual engineering problems wherever possible.

I am in no position to propose an actual curriculum; however, I should like to take the liberty of making a few suggestions which may aid in the preparation of curricula and their subsequent handling.

(1) *Consult industry in drawing up the curriculum.*

It is fortunate that there are men in industry today who are familiar with both the needs of industry and who have had experience with the problems of teaching college courses. These men would form excellent consultants for the university in the preparations of its curricula.

(2) *Employ men in industry as visiting lecturers.*

There are men in industry today who would welcome an invitation to spend one semester or one year as a visiting lecturer. Of course, the university must recognize that to induce a man to spend some time at a university, the stay must be made sufficiently attractive. I believe that this can be done since it is being practiced by leading medical schools in this country. To counteract any argument that his stay in the university would be too short to bear fruit allow me to point out that besides his teaching to students the university can greatly benefit from his talents in other ways; namely, he can aid in the preparation of curricula; he can participate in staff seminars where the present faculty can benefit from his experiences; and of course, he can be retained as an expert consultant. Furthermore, he would form a very personal contact between the university and a particular industry and we must agree that closer cooperation between the two is a most desirable feature.

(3) *Close consultation between the engineering department and the mathematics department.*

Although this point should be very obvious I regret to say that in my experience I have not always found this to be true. Certainly all departments can benefit by making proper use of each other and such cooperation must exist for the greater success of *any* program.

(4) *Permit the present staff members to obtain some industrial experience.*

I believe that this is already practiced by many engineering departments; however, that cannot be said of the mathematics departments. A few—perhaps too few—industrial concerns and governmental agencies have tried (and found it to be successful) to hire faculty staff members in a temporary capacity for a short period of time, usually during the summer months when normally the universities are not running a full schedule. The benefits derived from such a relationship are numerous to everyone concerned. For a more detailed account of this theory I should like to call your attention to a paper published in the *American Mathematical Monthly.**

However, we are here faced with two problems, (a) to sell more industries the idea and (b) to sell the universities the idea of granting leave if necessary for such experience, to encourage participation by its staff members, and to recognize its worth by appropriate promotions and raises in salary. Certainly, such experience adds also to the prestige of the university in the same sense that publications do.

(5) *Encourage staff members to attend applied mathematics schools, conferences and meetings.*

Leave of absence should be granted if necessary. The university should make every effort to obtain grants, fellowships, travel money, or other university aids to enable younger staff

* K. L. Nielsen, "Industrial Experience for Mathematics Professors," *American Mathematical Monthly*, Vol. LIV, No. 2, February, 1947.

members to take active part, and active participation should receive appropriate rewards.

(6) *Educate the engineers to the existence of this specialist.*

In all probability when this individual joins an industrial concern he will be associated with the engineering department and will be placed under the supervision of an engineer. Therefore, in order that a mathematical engineer or industrial mathematician may best serve the industrial organization, these engineers must recognize the proper manner in which he should be handled. The engineers must understand his capabilities, must not expect the impossible from him and must be able to recognize the worth of his work and understand his language. This man is a highly skilled scientist; he is not necessarily a design engineer. He can help the engineer in solving his research problems, but it can be done only with cooperation and understanding. Perhaps this education of the engineer should start with a more comprehensive appreciation of mathematics on the part of engineering professors.

4. *Conclusion.* As a concluding remark I should like to say that it is my fond hope that we may educate this scientist to the extent that he may take his rightful place in this modern technological world; that as engineers you will understand him and his place among you. It certainly behooves us as educators to train any and all kinds of scientists in order that we may benefit from their endeavors both as a society and a nation; and if the need be, that they may be ready to help us preserve our way of life should it ever be challenged.

Research Policies at M.I.T.

By JAMES R. KILLIAN, JR.

Massachusetts Institute of Technology

Since the war, the relationship of research to education has been under active and sometimes vehement discussion at my institution. I therefore welcome the opportunity of outlining our present policy and of removing from behind the ivory curtain certain vexing problems that we share with many institutions. The continuance of sponsored, *i.e.*, contract, research after the war has required new policies, some of which are still *subjudice*. Moreover, the large scale of much of this research has raised questions which can be summarized in terms of an old paradox, "Have we educationally bitten off more than we can chew or are we chewing more than we can bite off?"

Educational Uses of Research

Let me begin by discussing some current problems of integrating research with engineering education, deferring until later the special problems of contract research.

We all recall the "long hairs vs. hairy ears" argument that followed the war, and the repeated assertion that men trained in science, especially in physics, proved to be more effective at applied research than did the engineers. I feel that this assertion, if analyzed, can be shown to be a half truth. Nevertheless, the half truth that remains should force and is forcing a reexamination of some of our methods and procedures in engineering education, and of our use of research as a method of teaching.

The scientists ascribe their success in handling applied research during the war to several factors: The first is that they had advanced training and most of them held doctor's degrees. The second is that they had a fundamental training in science that was both broad and deep, with the result that they were able to bring to bear upon practical problems a wider range of scientific learning and a more flexible method of thinking. The third is that the training which they had received and the environment in which they had worked promoted creative thinking of a quite untrammeled kind. They were not normally concerned by any practical or economic limitations and they were instinctively inclined to dream and speculate, with a bold indifference to limitations.

Now this kind of training and this point of view are not a monopoly of the scientist, and there are fields of engineering which have embraced them for many years. The fact remains that engineering, while retaining its capacity to work under practical limitations, must at the same time adopt more of the analytical tools of pure science and its willingness to question standard practice. The feeling is widespread in many institutions that research must be used throughout our engineering training to attract men of imaginative

minds and to train engineers who have the temerity and capacity to dream and speculate beyond the boundaries of the immediately practical.

The engineering departments at most engineering institutions have long been wedded to the principle that research and the research atmosphere are essential to the training of both undergraduates and postgraduates and that a balanced staff must involve creative competence as well as teaching competence. I believe that this tendency to deepen engineering education through stressing fundamental research is one of the most important changes now in process. I believe, too, that while engineers must always maintain their firm hold on the economic and applied aspects of their art, they can enormously benefit by promoting within their ranks an increasing number of scholars with the courage to ignore conventional conceptions and with a comprehensive understanding of physical laws and analytical methods.

The Problem of Hardware

Our concept of what constitutes effective research in an engineering department is subject to another consideration. The scientist generally undertakes to investigate a phenomenon or to seek a principle or to collect data bearing on a hypothesis. Sometimes he may be interested in working on some component of a system, but rarely is he interested in a system. Engineers, of course, do this kind of research, too, but frequently they do another kind that results in some instrument or machine or process or an entire system. In the current jargon, the scientist is not interested in producing "hardware"; the engineer frequently and properly is. Is there a real danger that too much emphasis on hardware may reduce the effectiveness of engineering research in an educational institution?

We have been trying to clarify our own thinking as to when hardware, or the design of some entire engineering system, does provide a justifiable research objective. While realizing that there is no clear answer, we have concluded that if the hardware involves some new art and there is a great demand for men adequately trained in this art, then this kind of research can be vital. I cite as an example the field of control (including servomechanisms), an engineering art that is still under intensive development. Research in this field not only must look toward the production of an instrument as the end result but must comprehend an entire system, since the assembly and balance of the system is one of the essential research problems. There is a great need for men who are trained in the art of developing dynamic control systems, and consequently any laboratory activity must deal with the over-all system.

This emphasis on system research in the control field justifies another type of research which might commonly be out of place in an engineering institution. I speak of research which involves the production of equipment. In this and a few other fields, because of the importance of the systems aspect, the production of equipment involves a new art and a research technique which is essential in training men in the field at an advanced level. There is no other way for these men to become effectively trained other than to work on a project which involves the production of control units. More importantly a systems project or the engineering of a piece of equipment can be an extraordinarily effective educational

vehicle by requiring a synthesis of all that the student has learned.

We believe that research on hardware or systems should meet these tests of educational validity. We also believe that contract research should be subject to the same tests and should not overemphasize hardware.

The Organization of Academic Research

Another problem that has required much attention is the management and organization of research, especially that kind of research which is carried on by large groups of investigators. The war demonstrated the effectiveness of research teams, and we are now experimenting to determine how effective group research can be within an academic organization. In making this experiment, we are certain that research teams should never displace the brilliant individualist who works alone, but we want to find out how the two approaches supplement each other.

One of the devices which we are using to handle group research—and to stimulate individual work—is what we call "centers of research." These are interdepartmental organizations which coordinate the activities of various departments in important fields of overlapping interest. While we call them "centers of research" because research is their predominant role, they are nevertheless playing a very important part in our educational program, especially by providing superior opportunities for senior and graduate student thesis work.

These centers of research appear to be a highly satisfactory answer to a problem which has long confronted educational institutions, namely, that of handling those interests which reach outside the traditional departmental boundary lines and require the cooperation of the specialists from several disciplines. Certain institutions have tried to meet this problem by setting up special institutes. Others have set up new departments. It is our feeling that both of these solutions seem to be lacking in two desiderata: namely, the mobilizing of the interested personnel of the various departments into a cooperative whole while still recognizing each department's special interest in the various aspects of the program, and, most importantly, the full coordination of the research with the educational program.

We have established these centers of research in about half a dozen fields, but the first and the most highly developed of our programs is our Research Laboratory of Electronics, which is operated jointly by the Department of Physics and the Department of Electrical Engineering. Some sixty-five graduate students are now doing their theses in this laboratory. It has a highly productive program of research that is managed by professors from the two collaborating departments and it maintains a concentration of equipment which is available to the staffs of the two departments.

We believe that this laboratory is serving as a pilot plant for a new type of internal collaboration among departments having the fundamental scientific point of view and departments having the applied point of view. Through such mechanisms as this we hope to effect a fruitful cross-fertilization and thus minimize any invidious distinction between the engineer and the scientist. Joint laboratories of this kind also provide a means whereby the educational staff can cope with large-scale sponsored research. These laboratories provide a staff of administra-

tive officers and services which free the educational staff from routine work, thus permitting them to concentrate on their educational and research activities.

Contract Research—Its Values and Limitations

Coming now to some of the special problems of sponsored, or contract, research, I should like to state several guiding principles which we have laid down, and describe some inherent difficulties.

Our first guiding principle is that sponsored research should be closely related to the normal program and recognized objectives of the institution. It should involve only work which can be carried out with enthusiasm by the staff and it specifically should not be work which the staff would undertake with reluctance and which would be unrelated to their educational and professional programs. A member of our staff is never "assigned" to contract research.

Our second guiding principle is that imposition of restrictions on publication of research results, either for secrecy or patent reasons, can become incompatible with the basic concept of an educational institution as a source and distributor of knowledge. Research contracts involving such restrictions, especially long-term or permanent restrictions, should be undertaken only for exceptional or emergency reasons. No arrangement is permitted which could inhibit free and effective work by the institution in any scholarly field. No project is normally accepted unless it is open to qualified students.

Our third guiding principle is that the compensation and privileges available to the academic staff, including graduate students who are members of the staff, must never suffer in comparison with the compensation available to staff engaged solely for contract research. This policy is of the greatest importance, since funds available for contract research frequently are less restricted than funds available for the regular academic program, and there is a consequent temptation to pay higher salaries to the personnel working on these projects.

We have carried out this policy of protecting the academic staff by distinguishing sharply between our academic staff, with its educational function, and the nonacademic staff employed specifically for contract research. The academic staff has important privileges, such as tenure, membership in the pension association, opportunity for graduate study, time for outside consulting, and extended vacations. None of these privileges is available to the nonacademic staff.

The compensation for nonacademic staff, however, is usually somewhat higher than are salaries of comparable academic appointees. In securing staff for research projects, we have had to meet industrial competition in recruiting, and their status with us is quite comparable to what it would be in industry.

The same general policy applies to graduate students who have part-time staff positions. The nonacademic staff member who wants to take graduate work is limited to one subject per term and he may not present a thesis based upon sponsored research work for which he has received compensation at a higher rate than that available to the academic appointee. In contrast, the regular graduate student who also has an academic appointment as teaching fellow or research assistant receives a lower rate of pay but has full graduate

student privileges, including the opportunity to work on sponsored research and use this work for thesis credit, provided of course it has been approved and properly supervised.

Maintenance of these two rates of compensation requires some dextrous tightrope walking, and is a difficult administrative procedure. In practice, our Division of Industrial Cooperation, which manages our sponsored research, gives preference to the academic staff when it is recruiting personnel for a contract project, but if the project cannot be staffed from our academic group, appointments from outside the institution are made in accordance with the policy I have outlined above. Even though the salary scale may be somewhat lower for the academic staff, the academic appointment with the privileges it carries remains a more desirable appointment.

Related to this general policy is our limitation on supplementary compensation to academic staff members who work on contract research. Here we follow the policy that teaching and other normal academic duties must not be made less attractive than working on contract research. We share fully in the following recommendations of the Committee on Academic Tenure, Professional Service and Responsibility of the Engineering College Administrative Council:

"If equity demands that supplementary compensation should be paid for extra work within an institution, the amount of such additional compensation should not be so high that it tends to reduce the importance of the staff member's regular work and salary, and to place a value on contract research or nonacademic assignment that is high in relation to the value placed on the usual academic duties.

"Care must likewise be exercised to avoid compensation inequities within an institution which result when some staff members, whose field of work may attract outside research, receive large supplementary salary payments while other staff members, in fields of less immediate application, but possessing equal or greater scholarship and professional standing, receive from the institution only their regular salaries. No plan of supplementary compensation should put teaching in an inferior position or tend to divert staff members from their obligations to their students."

In practice, our staff members working on sponsored research have enough time released from academic duties to undertake the research. Out of approximately two hundred academic staff members working part time on sponsored research, less than twenty are receiving supplementary compensation. Those who receive this extra compensation agree, for the period they receive it, to forego their privilege of engaging in outside consulting.

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Other more detailed tests which we apply to sponsored research include the following:

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(b) It must be possible to staff the project in accordance with the institution's prevailing personnel policies.

(c) It must be possible to staff the project without handicapping our edu-

cational program either by overloading the staff or by diverting from the educational program the proper amount of attention and interest.

(d) Final approval of the project rests with the academic dean who has jurisdiction. If the project is border line and the dean has doubts whether it meets the tests and principles laid down, he will bring it before an administrative committee composed of the president, the vice president, the dean of engineering, the dean of science, and the director of the Division of Industrial Cooperation.

Reduced to a single statement, these principles say in effect that the consideration, acceptance, and priority of any sponsored research project are governed by the extent to which the proposed activity will carry forward the educational objectives of the institution.

In conclusion I would reiterate that research, aimed at advancement of knowledge or development of its practical applications, is both a method of advancing knowledge and a method of teaching and that it must be both when carried on in collaboration with students. In meeting this educational test, our research programs must also help to create that subtle kind of environment where scholarship and creative activity flourish and great minds feel at home. The creation of this kind of environment is one of the major tasks of our engineering institutions.

Contributions of Science and Technology to Education

By N. W. DOUGHERTY

Dean of Engineering, The University of Tennessee

This is my text:

"And he gave it as his opinion, that whoever could make two ears of corn or two blades of grass, to grow upon the spot where one grew before, would deserve better of mankind and do more essential service to his country, than the whole race of politicians put together."

("Gulliver's Travels"—Swift)

A few days ago there was an editorial in one of the Knoxville papers opposing the establishment of a Federal Science Foundation. For more than three years all of the national organizations, of which I am a member, have been working strenuously for such a measure. This difference of opinion is caused by a difference in understanding of what is meant by science, its development and its implications. Today I wish to talk a little about the contributions of science to education and in so doing I will trace briefly the movement toward originality and the questioning attitude.

Here in Memphis you make a special effort to cause a newcomer to feel at home. Should you find his basic philosophy out of tune with that generally accepted in your town you will, like citizens of all other communities, question his motives and resist his innovations. Leaders in education are the same leaders that we find in other activities. If innovation upsets their beliefs they resist and move into place their heaviest artillery.

Before developing the contributions of science and technology I will give a brief review of the battle between utility and non-utility. Sometimes I believe that Don Quixote has returned and is doing battle with his wind mills all over again.

The Beginning of Formal Education

The life of Lycurgus gives us a picture of education in early Sparta. It was strenuous and designed to fit the youth to take their places as men when they reached the age of citizenship. No doubt much of the training was not necessary for the purpose but the overall product succeeded in carrying on the traditions of a sturdy people. Utility was the watchword of all their education.

During the period of Athenian greatness again we had a regimen of training for citizenship but this time on a broader base than the training of Sparta. Plato enunciated the doctrine of "Philosopher Kings," or educated rulers of the state. He recommended that the wisest men be placed in charge of public affairs and then only after they had shown real aptitude for government. This is what we do in busi-

ness in America but too often we take the attitude that anyone, who can be elected by the people, can govern well. Our experience has shown that aptitude for government is as essential as free public choice.

When the European universities were founded they adopted curricula that were useful. Objectives were stated and programs developed to approach the stated objectives. Of course, always the curricula included known knowledge or known information. Whatever custom has dictated habit will continue until a crowding of the program will squeeze the old courses out. Throughout the Middle Ages the program was made up of the humanities, language, literature, speech, history, philosophy, architecture, music, the fine arts and mathematics. Since the books were written in Latin and Greek knowledge of these languages became the hallmarks of the scholar.

Probably the strangest thing in all education is the veneration with which the Ancient Languages have been held and the persistence of the oldsters that these languages have unusual educational value. True, the reason for their study has passed with the translations but the study itself persists as a mental discipline or as an aid to the learning of English. I don't object to anyone learning Latin and Greek who wishes to learn ancient languages but I do object to the notion that these languages are necessarily badges of educated people.

When once an idea or method is accepted it persists until uprooted by a substitute idea or method. Often the battle is long and the change comes many generations afterward. This persistence of the old poses a whole series of problems in modern education. New subject matter has been developed, new skills have been acquired and new methods have been devised. These have been superimposed upon the old way of doing things and as a result there has developed great differences of opinion as to the correct course to pursue. No simple answer is in the offing.

Some very distinguished educators decry the study of utility subject matter; others go to the extreme of "no utility, no study." If we follow the usual law of compromise we will accept a pathway somewhere in between these extremes. The doctrine of the mean, or of the middle of the road, is very old and it usually finds a workable plan. Let me illustrate the different points of view by quotations from an apostle of each extreme.

"But whatever the subject matter and approach, the main emphasis should always fall on understanding, or insights for their own sake, rather than on insights merely as a means of action and belief. Thus a liberal education should include the study of religion as an historical phenomenon, a type of human experience, and a pattern of belief . . . it should not demand acceptance of any specific religious beliefs or promote any specific religious practices. Its function is to enlighten, to promote understanding, not to proselytize. This applies not only to religion but to morality, art, and politics. In a democracy, it dare not even proselytize for democracy itself."

("Liberal Education Re-examined.")

Being a technologist I have always had difficulty with this point of view. It is strange that in a democracy, where one is permitted to hold these opinions, it is counted illiberal to say a good word for democracy. Our kind of religious belief will allow its followers to study all other kinds of belief, yet the follower must not say a good word for

his own religion. The study is to promote understanding and not to make converts. Now let us examine the other point of view:

"Knowledge, notwithstanding its great value to people generally, is not to be regarded as an end in education, but simply as a means to other ends which lie beyond. *It is those ends which are valuable,* rather than the knowledge, itself; and, unfortunately pupils can, and often do, acquire knowledge without attaining the ends at all."

("Permanent Learning."—W. H. Lancelot)

Here is one educator looking for knowledge for its own sake and another bothered because some students get knowledge for this purpose and not because of its utility. Down deep under the skin of both these educators we will find that they are both interested in the great task of living and, of necessity, they are interested in the coordinate task of making a living. One would emphasize the art of living, the other would emphasize the science of making a living and its implication on the living of others. Both are important; one cannot exist without the other. If we think of making a living as an integral part of the living we can begin to reconcile the two points of view.

To be a graduate of a technical school one runs the danger of overemphasis of the "doing and the getting" rather than on "the being and believing." Nearly always the doing and the getting makes possible the being and believing.

How does it come about that we are attending the commencement of a technical high school? It is a type of school which began in this country in 1824 and has grown in the 123 years to a real stature and satisfies a very pressing public need. Science as a method of thinking is very old though its growth and application is very new. Down the corridors of time men and women have applied the questioning method to their surroundings and have thus contributed to the sum total of science.

We usually think of the Prophets of Israel as religious leaders, and they were, but when they spoke against formalism, the substitution of understanding for sacrifice and the seeking of Jehovah for burnt offering they were following the spirit of freedom which is the spirit of science and technology. In the golden age of Athens there was a spirit of inquiry, a searching for the truth and at times men caught the spirit of freedom which led to originality and the breaking away from tradition which slavishly ties the human mind to accepted customs and denies to them future possibilities.

Then there settled down on the world a fog of tradition and status quo which we now call the Dark Ages. It was not broken until Columbus discovered America and men of good will began to question the authority of other men. Such sages as Galileo and Copernicus broke with the past and became the vanguard of a new method of thinking. For four hundred years men have sought out new things, new ideas, new methods until today we are beginning to understand the world about us and to postulate how it came into being, how it is maintained and how human beings can live together on it.

The change from the Dark Ages did not come in a day. It was a long hard struggle out of the night. We are at its morning tide rather than at its high noon or setting sun. As you go out into more education or into the life of the community you will take your

place in society at the beginning of a new age. You, and others of your kind of training, will have to learn how to control and manipulate this new strange world of atomic power.

No works, no achievement has fired the imagination of the American people like the activity at Oak Ridge, Tennessee. Right here in our State we have the number one research project of the World. Its possibilities stagger the imagination; its probabilities are taking very active shape both as an energy source and as a harbinger of new frontiers in medicine and biology. Its power has been demonstrated. When I saw the picture of a column of water 2,000 feet in diameter raised to a height of half a mile I was convinced that we had a power source which would compare with Vesuvius at its heyday. All we have to do is to develop its control and economical use, but power is probably not its greatest possibility. Radio-active isotopes may be used to study the life process, to find cures for dreaded maladies, and to prevent the recurrence of disease.

The effect on our way of living may be illustrated by a brief review of things we already know. In 1763 Watt began his work on the steam engine. The device was old at that time but it had not been improved to a desirable state of efficiency. Under Watt's genius the steam engine took form as we know it today and along with its development the world has changed over from the use of manpower to the use of steam power. If we tried to enumerate all the changes which have occurred our list would be very long. Three developments will be enough to illustrate what I mean. The factory system took the work from the home to the engine operated plant; the steam locomotive took the burden from the backs of men and animals and placed it on bands of steel; and the steam boat made obsolete vessels driven by wind and placed their control in engines far below decks. Should we follow the ramifications of these three changes which were due to the steam engine we would find that the path was strewn with misunderstanding and fears along with improvements and great advantage.

One more application of power will help us to vision the changes that may come with this new source of energy. In the 1880's the dynamo was developed to a usable machine. Faraday had discovered it fifty years before but its development and use waited for Edison and his genius for making useful things. For belts and gears were substituted wires, switches and resistances. A generator at one place could pull motors all over an area. Motors were developed of all sizes from that operated by the dentist to that housed in the electric locomotive. The factory system became the assembly line of operation and the home became filled with electric devices and gadgets. Our homes in 1947 are far different from those of our grandfathers before the turn of the century.

Now let us take a look at an idea which has changed practically all of our methods of treating disease. Louis Pasteur proved the germ theory of disease and by this one step he made possible the treatment of hundreds of diseases that had baffled the best minds before his time. Smallpox, typhoid fever, yellow fever, malaria, dysentery, food poisoning, and a hundred of others fell before the new onslaught. The life span was increased and many of the scourges of the Dark Ages were only things of history.

Here at our very doors may be a new

agent which will combine the changes of great power with the changes which came with the germ theory of disease. Your day will be a very interesting day in which to live.

Now let me come back to the warfare between utility and non-utility in education. The battle will probably not be won by either side but by a better interpretation than either side has given to this date. Utility cannot exist by itself; it must carry with it some of the very virtues claimed by the non-utility advocates.

What are some of the additions to education which have grown out of science and technology? First of all, there has been a raising of the level of manual skills for the whole population. In Watt's day the greatest handicap he had in making an engine was the skills of his workmen. Today hundreds of workmen have skills not possessed by a single workman at that time. The schools have assumed a responsibility in furnishing many skills which were acquired by the apprentice system a couple of generations ago.

During many centuries the race has developed methods of qualitative thinking; science has added a method of quantitative thinking. True, there have been people in every generation who have dealt in figures and balance sheets but the idea of accurate measurement is comparatively new. New for more reasons than one; first, there was little need for accurate measurements, and second, there was no equipment available for such measurements. Now science always asks, when, where, how much, how little, how accurate, what error, what tolerance, etc. To the educational process has been added all kinds of ways of making measurements and methods of determining their accuracy. It is important to know the quantity, the cost, the availability and the amount of work necessary to make a machine or a product ready for use.

Probably the distinguishing characteristic of our thinking over that of the ancients is the questioning attitude. As we measure quantities and we try to measure everything, we constantly search for magnitude. If it cannot be measured we raise a question about its very existence. No longer do we take statements on authority; we want authority to establish itself and prove that it has a right to speak. Oracles, divinations and seers have a hard time making places for themselves in our generation. A thing is not necessarily good because it is old, neither is it good because it is new; it is good because it serves a useful purpose and is suited to that purpose. There are few universals anymore.

I say we are wary of universals though we may be much nearer to them than ever before. For example, all matter may be one matter and certainly matter and energy are very much akin to each other, if not identical.

The experimental method offers a way to discover the soundness of a point of view or the conclusions from observations. It does not accept on authority unless the authority is bolstered by supporting data and it furnishes a method by which the data themselves may be tested.

Many are distressed that they cannot have authority in which to seek refuge. They do not care to do the testing, they do not desire to do the questioning and consequently have little need for the method of experimentation. They can go their merry way and believe as they please but should the sailing ever become rough, and they desire to test their position, they still may use the experimental method. True it de-

mands a certain amount of aptitude for good results, but the questioning is the beginning of the method.

Science has given us a concept of the nature of the world, the universe, and all living things about us. All will agree that it is more satisfying to see nature through the eyes of understanding than through the eyes of superstition and fable. The better the understanding the more able we are to find our place in this vast creation. The more we know about ourselves and our methods of thinking and the actions of our emotions the better will we be able to live with each other. Science has made long strides to such an understanding; more science will carry us farther in the way.

We have learned that efficiency in service means symmetry in lines and harmony of the parts. Here is a law which makes possible the production of a piece of art by the designer of a streamliner, the airplane or the skyscraper. Yes, we could name a dozen other contributions to esthetic construction and not exhaust the catalogue. Let us consider for a moment the automobile engine. It works under a hood, it is to be seen when being serviced or dismounted for repair, yet its lines are symmetrical, its form is not homely, and withal it is a thing of pleasing appearance. Its design is for efficiency and performance and not for beauty or appearance. Were I an orator or a painter I could make a good word picture or a canvas which will give you the idea that I am trying to express. As the scientist or technologist does his work well he creates machines, structures, and devices which may be contributions to art as well as contributions to his major objective of construction and production.

Finally let me emphasize utility in production and distribution as a part of the larger program of resource conservation. Wanton waste borders upon the criminal; careful use for real needs is a very high virtue. As any worker does his job well he is contributing to the general welfare of the community and state; he is conserving resources for his and future generations. Any instruction which emphasizes this phase of production and consumption is making a contribution to the general welfare of the state. We should commend such a program rather than condemn it.

Utility is a virtue when we are serving a real want; utility may be a vice when it causes us to fragment our knowledge and place small bits of it into labeled compartments without relation to the whole picture. Let us not be afraid of utility but let us shun extravagance and selfish greed which may come in the wake of utility. Efficiency is commendable; it will produce goods and services which will be an asset to us all.

Conclusion

Seventeen and eighteen years ago when you were being born there were those who cast aspersions upon the technologist. They said he was creating a Frankenstein monster which might turn and consume or destroy our way of living. We considered turning away from machinery and we tried to make work with pick and shovel, with rake and wheelbarrow. In some places we wore the leaves out by raking them so much. Then we decided that machinery had come to stay and the *"back to the hand tools"* was a snare and a delusion. When the war came we were right glad that we had not junked our skills along with our discarding of the laws of econom-

ics. We had our debt but we still had our skills and they were enough to give us production in spite of our loose economic structure.

There is a place in our society for every kind of knowledge. Each and every one of us has a right to learn whatever is useful and lawful, and there is no good purpose served when any of us points his finger at any others of us because of the form or bent of our study. There is an equality of all knowledge which should make us glad that some of us may have one kind of talents and someone else some other kind of talents that the whole scale of knowledge may prosper and grow in our midst.

Let us therefore conclude that science and technology have their place in our educational plan. They have fought for this place and they deserve it because they contribute to our thinking process, they add to our esthetic values, they help us harmonize our lives with our surroundings, they show us how we can conserve for the future, and they give us a better understanding of the qualitative thinking which is the heritage of the race. Let us, therefore, hold our heads high with a full knowledge that we will be able to contribute our fair share to the sum-total of education and that our knowledge is essential to the solution of the current problems of our day.

Judicious Programming of Structural Courses*

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Application of sound judgment and rational appraisal of all phases of our academic programs are paramount essentials at this time of increased demands on the civil engineering curriculum. Increase in humanistic-social studies within the scope of present curricula can be accomplished in one of two ways; either by reduction of technical and professional courses within the four year pattern, or by extension to five years. The latter choice, followed by several schools, is in the direction of least resistance and implies that the technical courses as now given are sufficiently satisfactory. However, since the majority has chosen to retain the conventional four-year program, reduction in quantity and, perhaps, quality appears to be inevitable. Our experience at the University of Washington suggests that problems arising from the present trend can be solved by judicious programming with the possibility of maintaining or improving both the quantity and the quality of structural courses.

Exactly twenty years ago, our curriculum in civil engineering was completely revised. At that time it was an accumulation of thirty years of miscellaneous courses haphazardly arranged, the result of pioneer growth typical of curricula in similar institutions. Each division in civil engineering was placed in a clearly defined pattern and alloted an amount of credit appropriate to its relation to the field. Twenty per cent of the upper division (junior and senior) credits were assigned to structural courses. It was decided that a continuous sequence of low credit courses was preferable to intermittent high credit courses. Twenty years of experience have proved conclusively the wisdom of that choice and, in addition, have served to reaffirm certain basic facts of learning which are substantiated by every day experience. They are not new discoveries but age-old principles which have fallen into disuse by our educational system at all levels, primary, secondary, and collegiate.

Several precepts, which are relevant to this dissertation, deserve to be mentioned. Admitting their triteness, while emphasizing their extreme importance, these simple statements provide the background of understanding for suggestions which follow.

A sequence of natural growth is the essence of any effective program of learning. The student must be aware that the program follows a clear path from his background to his objective.

Learning is attained by frequent, repetitive use. Items of major importance should be introduced as soon as possible and repeated as often as possible while

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those of minor importance can be placed accordingly.

Prerequisite training always falls short of expectations. Essential prerequisite material must be repeated in subsequent courses. Courses at the professional level do not completely attain their objectives and must be followed by continuous study on the part of the individual in the practice of his profession.

All progress requires change but indiscriminate change instead of producing improvement usually results in retrogression as attested by numerous examples in diverse fields including the scholastic. When changes in training for a profession are undertaken, provision must be made to remedy or neutralize errors as soon as they appear.

Engineering education is not the modern substitute for apprenticeship but is training for entrance into a profession. Minutia, trivia, and drill in techniques, should be subordinated and reserved for a term of internship in engineering employment; otherwise advancement beyond sub-professional levels will be made more difficult because of misspent academic training.

The adjectives "difficult" and "unfamiliar" are synonyms. Likewise, "easy" and "familiar" are identities. Any specified item of our special discipline is difficult only because it is unfamiliar. It is unfamiliar because of lack of proper relationship with its context.

A well-considered program embodying the aforementioned precepts is the single prime requisite for effective professional training. The diverse divisions of civil engineering have a common interest in structures. This does not mean that the structural division is the most important or that all civil engineers should be structural specialists. However, it does mean that the structural courses can provide the unifying stem of the upper division of the civil engineering curriculum. In order to serve this purpose, the stem itself must be unified.

Academic scheduling by school years and by quarter or semester terms complicates planning and increases the importance of coordination within the structural sequence. It is practically impossible to correlate sub-divisions of the sequence and the school calendar although they should be related to the greatest possible extent. At the outset, allocation of an appropriate number of credit hours throughout the third and fourth years should be the extent to which the calendar is permitted to affect the program.

Subdivision by function (bridges, buildings, dams, etc.) provides a system of classification but, being based directly on diversity, defeats the objectives of a program. Similarly, subdivision by material (wood, steel, reinforced concrete) fails to provide the pattern for exactly the same reason. Both systems are based on obvious differences and tend to accentuate these differences in spite of the best efforts to the contrary. Both plans have been tried and have fallen short of our expectations. Six separate compact compartments developed despite every effort to counteract the tendency.

The mechanics of structures is the common ingredient of our discipline, regardless of function and material. It is the obvious stem along which the information and details peculiar to special uses and particular materials can be appended. Classification by type of structure is not uncommon in both curriculum and literature but as currently used it contributes to greater diversity than subdivision either by use or by material. During the first fifteen years of our efforts toward satisfactory programming, several ten-

tative experiments suggested the feasibility of a mechanics stem. As a result, during the disturbed program of the war years with their accelerated tempo it appeared that failure of an experiment in programming would be insignificant compared to other deletorious influences over which we had no control. Also, it became immediately apparent that the prerequisite backgrounds of army and navy trainees were so diverse that direct repetition of the mechanics prerequisite was mandatory. Discarding all expectations of attaining peacetime objectives in quantity but fully maintaining our objectives of quality, structural courses were programmed on the mechanics stem.

Beginning with the roots of our discipline in the field of mechanics, a sequence of natural growth proceeding in a clear pattern from the familiar to the unfamiliar was followed. The "three problems of structures" appearing in our older literature were revived and incorporated into the pattern with favorable results. To recall, the "three problems" are:

1. Given a structure and the loads, to determine the effects expressed in stresses and deformations.
2. Given a structure and prescribed stresses and deformations, to determine the corresponding loads.
3. Given the loads and dimensions, to design a structure which is adequate and economical.

Inspection of the basic aspects of the three problems reveals that they embody in natural order the procedures of our specialty. First, interpretation of facts gained by experience and experiment provides theory and specifications. Second, the theory and specifications are verified by further experiment. Third, application of theory and specifications provides a structure to satisfy a need. Briefly, the first and second procedures are "theory" and the third is "design." Accordingly, the first year of the program is devoted to theory and the second is chiefly design.

Appraisal of all types of structures reveals the obvious fact, commonly disregarded, that a structure is an assembly of solid materials which fulfills its functions by acting as a unit. Whether it be an airframe or a retaining wall, its members are no longer discrete portions but are components of an integrated whole which inevitably participate in the action of the whole. The unity of action of the structure itself suggests the unity of treatment essential to an integrated program. The adequacy of a structure is determined by the adequacy of each member and its connections to resist rupture and excessive deformation. Thus, the key to our present program is introduced in the form of the typical structural component which is subject to the actions of loads immediately applied to it and all other actions transmitted to it through its connections.

From the conventional viewpoint, this approach to the subject is fraught with almost insurmountable difficulties. Arising from unfamiliarity with fundamental prerequisite mechanics and mathematics, they can be overcome by proper presentation of basic mechanics and mathematics at the structural level. When coordination of prerequisite courses in mechanics and mathematics is obtained, much time and misdirected effort will be saved. Lacking this coordination, the remedy is the responsibility of the

structural division. This can be done only by reintroduction of prerequisite material in a form and language consistent with the pattern which is to be developed. For example, $M = A \text{ Sin } kx + B \text{ Cos } kx + f(w)$, the equation of general flexure should be developed and applied. The need justifies the effort which will be rewarded many fold. The situation is the more difficult because mechanics has impressed the student as a heterogeneous miscellany of unrelated special cases and formulas expressed in terms of a mystical philosophy known as mathematics. This unfortunate situation exists because of failure to understand that mathematics is simply a precise, rather limited, and very useful language, instead of a philosophy which contains the secrets of the universe.

A sequence of natural growth, mentioned previously, is the most important requirement of an effective program. It must have its beginning in familiar, basic fact and follow a path of orderly development toward its objective. There is no doubt that the structural sequence originates in mechanics, particularly mechanics of materials. In that subject the two basic facts and the two fundamental hypotheses from which the whole of structural theory springs are introduced and applied in their simpler aspects. The two facts are: (1) The Principle of Equilibrium, inherent in the very nature of force, and (2) The Axiom of Superposition, the whole is the sum of the parts. The two hypotheses, by means of which observations are idealized to permit simple mathematical statements, are: (1) Navier's Hypothesis of the linear distribution of force, and (2) The Hypothesis of Elasticity, which supposes direct proportionality of force and displacement. All structural theory and the tools for its application are derived by abstraction and approximation from these four elements.

Prerequisite preparation, even though it be of superior quality, can supply the materials but cannot construct the foundation of the structural program. The foundation must be provided by the structural division. Too often, this essential requirement is not fulfilled because of our impatience to cover an extensive field in limited time. Neglect of this obligation vitiates against attainment of our objectives. Repetition of the four elements of mechanics and a summary of essential mathematics are the materials for the foundation.

Basic material should be reviewed at the structural level. Several plans have been tried. To this time, the most effective approach describes structures as massive, framed or special. A massive structure such as a gravity dam, provides the opportunity to consider force characteristics, superposition and Navier's Hypothesis. It must be remembered that the object is not to analyze a dam but to review the fundamental principles and procedures. Explanation of Navier's Hypothesis apart from elasticity, to which it is not related, is highly desirable. Special structures include suspensions, arches, thin shells, etc. and are not included in the required undergraduate sequence but are given in specialized elective courses.

Framed structures are defined as assemblies of two kinds of components: (1) Panels, including sheets, plates and slabs, and (2) Members, including beams, columns, struts, ties, etc. The panel is regarded as a special kind

of member, being relatively thin, wide, and long, which may span in two directions. Types of framed structures are:

1. Panel, composed entirely of panels joined along their edges.
2. Rigid frames, composed of members, with or without panels, integrally joined and subject to loads applied within the spans.
3. Trusses, composed of members joined in a pattern of triangles subject to loads applied at the joints.

The typical member, common to all types of structures listed above, is a practically straight portion of theoretically elastic material, usually of uniform cross-section, which is attached at its span-ends to span-ends of similar members. It participates with them in transmitting loads and resisting rupture and deformation. Consideration of an illustrative typical member provides an introductory picture of its participation as a component in the behavior of the structure as a unified whole. The typical member, in general, is subject to a complex force distribution at its span-ends which is arbitrarily simplified to the conventional four components: direct, moment, shear, and torsion. Determination of stress intensities and deflections within the span cannot be made until span-end conditions are known.

All structures are supported by the earth or some intervening structure. External attachments of structural assemblies include innumerable possibilities. For purposes of calculation the range of possibilities lies between the lower limit of the hypothetical frictionless hinge or knife-edge and the upper limit of full fixity. The single-membered structures are the cantliever, simple, supported cantliever, and fixed beams, columns, and shafts of basic mechanics of materials. All are characterized by hypothetical span-end conditions. Each is a special, idealized case of the general member.

The foregoing description is not intended as instruction for those who are familiar with the field but to suggest the picture that should be presented to the initiate. From this point, the natural next step is the study of structures of two members, the elementary truss and the elementary rigid frame. In this connection, the fundamental tools should begin to take shape. The distinction between primary and secondary effects in both stresses and deflections should be emphasized and verified by theory. This requires the introduction, probably for the first time, of the subjects of general flexure and the derived concept of elastic energy. Proficiency in the language of mathematics is required for this purpose. Time and effort devoted to the development of this proficiency is an investment if for no other reason than to reveal mathematics as a servant rather than a master. Sastifactory results cannot be obtained during the first year although they may begin to appear during the second year. Time is required to erase the imprint of years of indoctrination.

At this point natural division of the sequence will appear: (1) the mechanics of the structure and (2) the mechanics of the member. The former is unrelated to the material and includes reinforced concrete, steel, and wood without distinction. The latter is specifically characterized by the material. Also, the structure must be analyzed before its members can be

studied. Unfortunately, when this order is reversed and structural members and connections are considered without regard to the behavior of the entire assembly, effectiveness of the program is enormously reduced. Mechanics of structures and mechanics of materials can proceed simultaneously; one supplements rather than interrupts the other.

After the general member is presented and the conventional single-membered structures are reviewed, two paths appear which cannot be followed simultaneously. The alternatives are rigid frames and trusses. The choice is a matter of personal preference since valid reasons can be found for either. Our experience indicates that rigid frames followed by trusses offers more opportunity for correlation with mechanics of materials and consideration of loads on structures. In addition, it provides for the early introduction and subsequent repetition of the more important fundamental principles and tools. The program is planned so that all fundamentals of theory can be developed in the junior year.

The program of the senior year repeats that of the junior year in about the same order. Theory is treated by reference and repetition (not duplication). The techniques of design, application of specifications and codes, and practical aspects of construction can be given the attention which they deserve. A fairly comprehensive view of the whole of structural theory gives a background for the development of structural judgment. Simultaneous consideration of the three materials in design studies contributes much in this respect. For example, the design of a short span highway bridge in each of the three materials arouses greater interest and provides more professional training than the same time and effort applied to an imposing structure of one material. Aside from the subject, the word "assume" has been dropped from our vocabulary because there is a natural sequence in each structural design similar to that of the program itself which discredits the assumption method appearing throughout the texts as either fortunate guesses or preguessing a problem that has already been solved.

There are several practical disadvantages to the type of program just described. Current textbooks are not adapted to this order of treatment and teaching by the conventional textbook method cannot be used. Several books are needed for reference in each course resulting in a small library by the end of the sequence. As a result, the student has used but a small portion of each book and is inclined to be overcritical of the book requirements and of the books themselves. A considerable amount of supplementary material is needed to simplify complex treatment by the authors and to modernize current books by making up the five to ten year lag that seems to be unavoidable. The full two year program for a given class must be fixed in advance and all instructors who participate in it must be fully cognizant of any changes that may be necessary in order to avoid omissions and duplications.

Accurate self-appraisal is both improper and impossible. Evaluation of the experiences of our graduates together with their counsel and frank criticism attests the value of judicious programming. It is very clear that

careful planning of a sequence is the most important factor for the improvement of structural training. There is nothing novel in beginning at the beginning and deliberately proceeding from the familiar to the unfamiliar along a sequence of natural growth with frequent repetition of the important principles and tools. Also, following a path into an extensive field of knowledge guided by the pattern of that sequence is not extraordinary. However, it behooves us to pause and consider our ways from time to time in order that we can better serve. Many problems of the present day can be resolved by application of time-proven principles and diligent effort.

The limited scope of this presentation leaves much to inference and implication. Emphasis of the importance of programming, the characteristics of an effective program, and suggestions to those considering program changes are its objectives. Prescription of precise details has been avoided. Description of successes and failures would fill many pages. May our efforts encourage those who strive to increase the effectiveness of professional training to the end that attainment may approach our highest aims.

Necrology

Joseph Peter Connolly, President of the South Dakota School of Mines and Technology since 1933 and associated with that institution since 1919, died October 7, 1947, after a lengthy illness.

President Connolly, a leading state figure in the field of geology and science was the author of numerous bulletins on mineralogy and the economic geology of the Black Hills and was also a contributor to the National Geographic magazine and other journals. In 1940 he served as leader of the National Geographic Society-South Dakota School of Mines joint paleontological expedition. He was a member at large of the state committee on economic development, member of the South Dakota Natural Resources Development commission, an honorary member of the executive board of the Black Hills Area Council of Boy Scouts, a member of the Lumber and Mining committee of the Rapid City Chamber of Commerce, and in 1933-34 was vice president and director of Civic Improvements Inc. Dr. Connolly had been a member of the A.S.E.E. since 1937.

Progress Report of the Committee on Undergraduate Curricula*

Purpose

The Committee on Undergraduate Curricula of the American Society for Engineering Education was appointed during the past year to study and to make recommendations to the Society regarding the requirements to be met in building undergraduate curricula and the most effective methods to be applied in educating prospective engineers.

Committee Assignments

The early activities of the Committee have been confined to a study of chemical, civil, electrical, industrial, mechanical, and metallurgical engineering curricula. As the work progresses, the Committee may recommend extension to other curricula.

Six Subcommittees, as listed below, have been formed with the membership of the original Committee:

Subcommittee on Chemical Engineering

Joseph C. Elgin (Chairman)
Robert M. Boarts
Thomas K. Sherwood

Subcommittee on Civil Engineering

Robert B. H. Begg (Chairman)
Clarence L. Eckel
Frank Kerekes

Subcommittee on Electrical Engineering

Paul Cloke (Chairman)
John H. Lampe
Joseph Weil

Subcommittee on Industrial Engineering

Ralph M. Barnes (Chairman)
David B. Porter
Ray L. Sweigert

Subcommittee on Mechanical Engineering

David L. Arm (Chairman)
Llewellyn M. K. Boelter
Harry L. Solberg

Subcommittee on Metallurgical Engineering

Robert F. Mehl (Chairman)
John Chipman
Matthew A. Hunter

Approach to the Problem

Engineering education has been beset by special difficulties, some fairly subtle. This is doubtless due in part to disagreement within the profession as to the essential qualities that should characterize an engineer. We need to determine our position so that we may progress from that point.

The first necessity is for careful planning as to education in engineering. Is is of vital importance and cannot receive too much attention from the national professional societies. For any given branch of engineering it must be decided:

*Presented at the Fifty-fifth Annual Meeting of the A.S.E.E., Minneapolis.

1. What is the scope of the branch of engineering in question;
2. What qualities—what abilities-to-do—are needed in the graduate;
3. What is the body of information that must be learned if the graduate is to render maximum service in the field;
4. How may a curriculum be assembled which will provide both the required body of information and the training necessary to develop in the student the qualities needed.

Each Subcommittee of the Committee on Undergraduate Curricula is now engaged in preparing what the members of the Subcommittee consider the ideal undergraduate curriculum for the field of engineering designated. In considering these curricula, the Subcommittees have not felt it desirable at this stage to attempt a listing of specific courses, course content, or time distribution and allocation. It is realized that such a study will take several years to complete and that as background material the general objectives of engineering curricula should first be determined. This report concerns those objectives—the qualifications, criteria, and ideals which it is felt the engineering curricula should strive to meet.

General Objectives of Engineering Curricula

In its first approach to the problem, the Committee accepted the aims and scopes of engineering curricula as prepared by the Committee on Aims and Scope of Engineering Curricula and published in the March, 1940, issue of the JOURNAL OF ENGINEERING EDUCATION, and also as stated in the May, 1944, issue of the same JOURNAL in the report of the Committee on Engineering Education After the War. The American Society for Engineering Education and the Engineers' Council for Professional Development have accepted the aims and scopes of engineering curricula presented in these two documents. To the conclusions of the two ASEE reports our Committee wishes to add two new elements of purpose:

1. To cultivate competence in dealing with human, as well as social and engineering problems; and
2. To unify in the mind of the prospective engineer the courses of his curriculum by employing in all of them the same fundamental approach to problems.

The problem of the four- versus the five-year curriculum has been discussed for many years. This Committee believes that by proper attention to the problem of undergraduate teaching the work to be done in the training of the student for the bachelor's degree not only *can* but *should* be done in four years, and that a fifth year at the undergraduate level merely subtracts a year from the student's professional life. The Committee is therefore working on the assumption that four years of training can equip the student with sufficient basic knowledge and facility in applying that knowledge to enable him to enter an internship in the engineering industries or to continue further studies. This conclusion conforms with that reached by the Committee on Aims and Scope of Engineering Curricula,[1] as follows:

"Engineering colleges serve diverse functions and prepare men for a wide range of technical, administrative, and

[1] Report of Committee on Aims and Scope of Engineering Curricula, JOURNAL OF ENGINEERING EDUCATION, Vol. XXX, No. 7 (March, 1940).

executive responsibilities. Technological education should, therefore, be kept widely available, and engineering colleges must continue to serve a correspondingly wide variety of purposes. They should not limit their aim to preparing young men for professional registration and practice.

"The present flexible arrangement of four-year undergraduate curricula followed by postgraduate work will better meet the needs served by engineering education than will longer undergraduate curricula of uniformly prescribed duration."

In preparing its report, the Committee will also consider the question of entrance requirements. There can be no doubt but that much of the difficulty in engineering education originates in the lack of articulation between pre-college and college training. What is needed is cooperative effort between the two. However, the matter is broader than that and will be taken up and discussed more fully by this Committee. Attention was drawn to the importance of selection and admission of students by the Committee on Engineering Education After the War,[2] as follows:

"Two problems stand out as of great importance: (1) Devising more valid means than have been employed in the past for selecting and admitting students and insuring better preparation in secondary schools, and (2) building up facilities not only to the pre-war level of effectiveness but well above that level. Engineering education can never advance beyond the qualifications of its students and teachers. Hence, the engineering profession, industry, and the public who have a vital interest in its welfare, should vigorously support every possible means of improving the quality of its personnel."

What factors must combine now to keep the engineering profession abreast of the other great professions and to assure the engineer his rightful place in society? By design, let us make the training of the engineering student broad; let us encourage him to make the rest of his life follow the same pattern.

The engineering graduate should be very firmly grounded in three fields:

1. *Basic science and mathematics.* The engineer must be sufficiently well trained in fundamental science to have a genuine grasp of the science involved in his work. This grasp must be good enough that he may put it to use, that he may turn instinctively to science to disentangle a problem, and that he may work with scientists cooperatively upon a problem. His familiarity with science in a general way must be great enough that he may continually be able to apply the results of old science and of new current science to his work.
2. *Engineering.* The engineer must be thoroughly grounded in engineering principles and techniques so that he may deal creatively with engineering problems. Engineering education today verges between the extreme right of emphasis on current engineering techniques to the extreme left of nearly complete absorption of pure science. The Committee holds that heavy emphasis on pure science precludes the teaching of true engineering and that heavy emphasis on techniques promotes only the repetition of old tech-

[2] Report of Committee on Engineering Education After the War, JOURNAL OF ENGINEERING EDUCATION, Vol. 34, No. 9 (May, 1944).

niques and does not promote the development of new ones. The aim should be a little left of center, toward the pure science side of the median point between the extremes, for engineering turns steadily toward more complex analysis and toward the employment of increasing amounts of science, and the colleges must lead in this.

3. *Social-humanistic subjects.* These are additional subjects aside from the technical and scientific part of the curriculum. It is their purpose to develop the student so that he may play the part of a citizen in local, in national, and in world affairs.

What composite constitutes engineering? The engineer must be able to operate in fields that physical science does not enter in a primary way—the human relationships of complex organizations, the operation of established processes with the full recognition of the factors of efficiency, of costs, and of quality. He must have a sense of practicality, resting upon a knowledge of established techniques and what they can be made to do. He must have a sense of responsibility to see a job through. He must have engineering judgment. The fusion of the recognition of a practical need, of orderly thinking in scientific terms, of newly applying scientific principles or applying new scientific principles, of applying approximations to situations where exact analysis is too difficult, of the reconstituting of old elements into a new combination providing a new result, of assessing the features of a process as to practicality in terms of the attendant circumstances relating to human relationships, to availability, to costs, and to markets, to the end that new, or better, or cheaper products be made available to industry and thus to society—this composite constitutes engineering.

Industry is rarely interested in employing a graduate for what he *knows* only; it is far more interested in what he can *do*. Not only that—his entire future is largely dependent upon his ability to continue to learn "on his own," both from study and from experience, after graduation. When the needs of industry and of the graduate himself are so clearly defined, it is the definite responsibility of our profession and of the colleges which train engineering students to cooperate in the engineering educational program.

Conclusion

The Committee on Undergraduate Curricula greatly appreciates the help it is receiving from interested members of the American Society for Engineering Education and will look forward to any further assistance in the way of comments or suggestions as its work progresses.

WEBSTER N. JONES,
Chairman

Recommended Visual Aids in Industrial Arts*

By HAROLD R. NISSLEY

and

THE CLEVELAND CHAPTER, SOCIETY FOR THE ADVANCEMENT OF MANAGEMENT

Because of the vast number of films produced during the war—some good, some not so good—a dozen or more catalogs are available, listing all or most of the 16 millimeter films produced in the last ten years. No attempt is made at evaluating any of these visual aids. A prospective user must, therefore, do some research if he is to get a film that will fit well into a program or put over a story.

It was to serve as a first course screen that a study was made by the Society for the Advancement of Management (Cleveland Chapter) to find out what management films were worth showing. Sixty-four educators in sixteen of the country's leading universities and a few management people were asked to list the best films in their respective fields. The response to this inquiry was so great that it was decided to break the study down into convenient "packages." One such package, "Recommended Visual Aids for Supervisors," appeared in the August issue of *Factory Management and Maintenance*. Another, "Recommended Visual Aids in the Field of Motion and Time Study," will be published shortly. This is the last in the series.

It is hoped that the following list of films, by no means all-inclusive, will be a more reassuring list than that offered by the typical catalog—that it will save the time of those responsible for getting up a program or integrated series of meetings. The reader should bear in mind that this list is merely a first screen; the chances are better for getting a suitable visual aid from this list than a random selection from a catalog. But the safest plan—always—is to view a film before showing it; such a preview will give the program chairman the possibilities and limitations of his visual "prop"; for what might be a good picture for one audience might be unsatisfactory for another group.

All films are 16 mm. unless otherwise specified. The running time on 16 mm. movies may be judged by multiplying the footage by 0.04 minute in the case of silent and 0.025 minute in the case of sound movies. Thus the running time for a 575 foot sound film would be around 14.4 minutes.

The films in this list had all shades of recommendations—from "fair" to

*Space will not permit full acknowledgment of all the help given in this survey. But I would like to mention at least three people who contributed most to the study: Mr. Daniel Vaughan and Miss Adele Masilonis, both of the General Electric Company; and Professor Judson Neff of the Graduate School of Business, Harvard University. The first two collaborated with the writer in the classification. Professor Neff had several hundreds of his cards in his film card file microfilmed; this Graduate School of Business file contains the data and professional comments on the majority of management and industrial films produced in the last ten years.

"excellent." It should be understood, further, that a film might be "excellent" for a group of foremen but might not be good for a group of college freshmen. Thus this list of recommendations should serve merely as a first screen to anyone setting up an integrated program. It is hoped, then, the following list will save the time and expense of frequent inspection trips and in other ways augment the teaching skill that is required during these days of large classes and insufficient faculties.

Recommended Visual Aids in Industrial Arts

Glass

Title	*Source*	*Recommended By*
Romance of Glass, The Sound, 1250 ft.	Pittsburgh Plate Glass Company, Pittsburgh, Pennsylvania	J. Neff, Harvard
You and Owens Sound, 950 ft.	Owens-Illinois Glass Co. Toledo 2, Ohio	J. Neff, Harvard

Machinery

Turret Lathes Sound, 1200 ft.	Gisholt Machine Co. 1245 E. Washington St. Madison, Wisconsin	R. S. Lindenmeyer, Northwestern
Turret Lathes—Their Operation and Use Sound, 1600 ft.	Gisholt Machine Co. 1245 E. Washington St. Madison, Wisconsin	H. P. Goode, Stanford
War Against Waste Sound, 935 ft.	Caterpillar Tractor Co. Peoria 8, Illinois	J. Neff, Harvard

Machining

Charing and Operating a Cupola Sound, 450 ft.	U. S. Office of Education, Washington, D. C.	J. Neff, Harvard
Chips Sound, 1200 ft.	Warner and Swasey Cleveland, Ohio	H. P. Goode, Stanford
Countersinking, Counterboring and Spotfacing Sound, 725 ft.	U. S. Office of Education, Washington, D. C.	J. Neff, Harvard
Double Ram Vertical Surface Broaching Sound, 1000 ft.	U. S. Office of Education, Washington, D. C. (Castle Films)	J. Neff, Harvard
First Principles in Grinding Sound, 1550 ft.	Educational Service Dept., Carborundum Co., Niagara Falls, N. Y.	J. Neff, Harvard
How to Machine Aluminum Sound, 1200 ft.	Aluminum Company of America, Pittsburgh, Pennsylvania	H. P. Goode, Stanford
Locating Holes, Drilling, and Tapping in Cast Iron Sound, 600 ft.	U. S. Office of Education, Washington, D. C.	J. Neff, Harvard
Single Ram Vertical Surface Broaching Sound, 950 ft.	U. S. Office of Education, Washington, D. C. (Castle Films)	J. Neff, Harvard

Oil

Title	*Source*	*Recommended By*
Sincerely Yours SOUND, 950 ft.	Sun Oil Company 1608 Walnut Street Philadelphia, Pa.	J. Neff, Harvard
10,000 Feet Deep SOUND, 750 ft.	Shell Oil Company 787 Commonwealth Ave. Boston 15, Mass.	J. Neff, Harvard
Under the Hood SOUND, 1500 ft.	Socony Vacuum Oil Co. 205 Sixth Avenue Cambridge, Mass.	J. Neff, Harvard

Plastics

Careers for Cellulose SOUND, 875 ft.	Hercules Powder Co. Wilmington, Delaware	J. Neff, Harvard
Origin and Synthesis of Plastic Materials SOUND, 640 ft.	U. S. Office of Education, Washington, D. C.	W. A. Wittich, U. of Wisconsin
Plastics SOUND, 2000 ft.	Breskin Publishing Co.	R. S. Lindenmeyer, Northwestern

Rubber

Building of a Tire, The SOUND, 950 ft.	Firestone Tire & Rubber Co., Akron, Ohio	J. Neff, Harvard
Rubber Goes Synthetic SOUND, 700 ft.	Colonial Beacon Oil Co. 278 Stuart Street Boston, Mass.	J. Neff, Harvard

Steel

Bridging San Francisco Bay SOUND, 1600 ft.	U. S. Steel Corp. Film Distributing Center, 71 Broadway New York, New York	J. Neff, Harvard
Making and Shaping of Steel, The SOUND, 70 ft. SILENT, 105 ft.	U. S. Steel Corp. 71 Broadway New York, New York	H. P. Goode, Stanford W. S. Karabag, U. of Pa. J. Neff, Harvard W. A. Wittich, U. of Wisconsin

Other Metals

Magnesium, The Miracle Metal SOUND, 1420 ft.	Atlas Educational Film Co., 1111 South Blvd. Oak Park, Illinois	J. Neff, Harvard
Metal Without an Equal SOUND, 700 ft.	Ampco Metal, Inc. Milwaukee, Wisconsin	J. Neff, Harvard
Sand and Flame SOUND, 800 ft.	General Motors Detroit, Michigan	J. Neff, Harvard
Story of Metal Bellows, The SOUND, 1100 ft.	Fulton Sulphon Company Knoxville 4, Tennessee	J. Neff, Harvard

Title	Source	Recommended By
Textiles		
Facts About Fabrics SOUND, 875 ft.	E. I. DuPont de Nemours and Co., Inc. Wilmington, Delaware	J. Neff, Harvard
Rayon, A New Frontier of Progress SOUND, 1600 ft.	American Viscose Corp. 350 Fifth Avenue New York, New York	J. Neff, Harvard
Welding		
New Horizons in Welding SOUND, 1000 ft.	Harnischfeder Corp. 526 Statler Office Bldg. Boston 15, Mass.	J. Neff, Harvard
Unionmelt Welding—An Electric Welding, Process SILENT, 300 ft.	Linde Air Products Co. 1517 Superior Avenue Cleveland 14, Ohio	J. Neff, Harvard
Miscellaneous		
From Mine to Market SOUND, 1600 ft.	Phelps Dodge Corp. 40 Wall Street New York, New York	J. Neff, Harvard
Story of Shoes SILENT, 800 ft.	Medville Shoe Corp. 25 West 43 Street New York, New York	J. Neff, Harvard
Sugar SOUND, 1025 ft.	U. S. Beet Sugar Assoc. Business Films 2153 K Street, N.W. Washington, D. C.	J. Neff, Harvard

ECPD Resumes Accrediting of Engineering Curricula

A three-year program of re-inspection of engineering schools for the purpose of accrediting engineering curricula was announced by D. B. Prentice, President of Rose Polytechnic Institute and retiring chairman of the ECPD's Committee on Engineering Schools, at the annual meeting of the ECPD in Montreal, October 24 and 25. Committees have been selected and the program of re-inspection is now under way in some parts of the country. This work will continue under the direction of H. T. Heald, President of Illinois Institute of Technology, who succeeds Dr. Prentice as chairman of the Committee on Engineering Schools.

An objective of the accrediting program is the establishment of "criteria for colleges of engineering which will insure to their graduates a sound educational foundation for the practice of engineering." It is also an objective of the ECPD to "establish and maintain an authoritative list of accredited engineering curricula to be available to state licensing boards, the engineering profession, educational institutions, prospective students, and the general public."

Inspection is made upon invitation from the institution desiring to be considered for accrediting. Visiting committees, selected on the basis of the curricula to be considered, inspect the school and report their findings to a regional committee which, after consideration of all available information, submits its tentative recommendations to the Committee on Engineering Schools. The final decision of accrediting rests with the ECPD. In chemical engineering, the inspection committees are selected by the American Institute of Chemical Engineers in collaboration with the ECPD's Committee on Schools. The findings and recommendations are then reported to the Committee on Schools of the ECPD. A curriculum may be fully accredited, provisionally accredited, or not accredited. Published lists include only the first two categories. Provisional accrediting is based upon conditions which the ECPD has found not to be satisfactory, but which the institution has given satisfactory evidence of remedying in the near future.

The ECPD has no desire or authority to impose any restrictions or standardizations upon engineering colleges. In fact, it is a stated policy of the ECPD to avoid rigid standards and to encourage well-planned experimentation. The original accrediting program was carried on from 1935 to 1937. It was planned at that time to re-inspect each institution at intervals of from three to five years. Because of the war, however, inspection was held to a minimum during the past five years. The Committee recognizes the fact that abnormal post-war enrollments complicate the operation of engineering colleges and may impair the effectiveness of instruction, but it is believed that the benefits which can be derived by a new accrediting program justify proceeding with the re-inspection under present-day conditions.

A program of inspection and accrediting of technical institutes will be inaugurated by a Subcommittee on Technical Institutes headed by H. P. Hammond, Dean of the School of Engineering, Pennsylvania State College. Technical institutes which claim to produce qualified engineers or which grant baccalaureate degrees will not be recommended for accrediting by the Subcommittee on Technical Institutes.

Of the 167 degree granting institutions in the United States, 143 have been inspected (not including re-inspections) and 134 have one or more engineering curricula accredited. At the present time, 508 curricula in various schools have been fully accredited, 80 provisionally accredited, and 104 not accredited.

The Measurement and Guidance Project, under the direction of K. W. Vaugn, is proceeding on a program of four levels of examinations. These include: (1) an Engineering Science Aptitude test suitable for the guidance of secondary school students at the sophomore level, (2) the Pre-Engineering Inventory tests for students who have completed secondary school education and are contemplating taking engineering, (3) a series of Engineering Achievement tests for sophomore engineering students, and (4) specialized examinations for graduates of the various branches of engineering. The Pre-Engineering Inventory tests are now used by over fifty engineering schools as an adjunct in the selection and guidance of freshman students.

A proposal has been made by a committee appointed by the Carnegie Foundation for the Advancement of Teaching to consolidate the principal examining agencies into one cooperative non-profit testing organization. This organization would embrace the College Entrance Examining Board, the Cooperative Testing Service of the American Council on Education, the Graduate Records Office, the Measurement and Guidance Project of the ECPD, and others. In order to maintain its present position in the engineering achievement testing program, ECPD has accepted membership on the Council of the American Council on Education. Such a cooperative testing agency would avoid costly duplication of automatic tabulating machinery needed to score the tests and would serve to pool the experiences of experts in the testing and guidance field.

The Committee on Student Selection and Guidance of the ECPD, headed by C. J. Eckhardt, is distributing posters to secondary schools and college preparatory schools giving information on the personal qualifications and preparation necessary for success in a career of engineering. These posters supply much needed information for the self-appraisal of secondary school students who are contemplating engineering as a career.

The newly elected officers of the ECPD include J. W. Parker, chairman; H. S. Rogers, vice chairman; A. B. Parsons, secretary; S. L. Tyler, assistant secretary; E. H. Robie, chairman of the Committee on Information; C. J. Eckhardt, chairman of the Committee on Student Selection and Guidance; H. T. Heald, chairman of the Committee on Engineering Schools; Scott B. Lilly, chairman of the Committee on Professional Training; Ole Singstad, chairman of the Committee on Professional Recognition; D. C. Jackson, chairman of the Committee on Principles of Engineering Ethics; and H. P. Hammond, chairman of the Subcommittee on Technical Institutes.

A Machine Tool Designer's Thoughts on Engineering Education*

By B. P. GRAVES

Director of Design, Brown and Sharpe Mfg. Co.

Limitations to our Proposals

Although there are probably many of your students who would enjoy this opportunity of telling you what should be done with engineering education, it is an assignment which a mature machine designer hesitates to accept. I cannot tell you specifically what to teach, nor can I suggest how to teach it. At best I can but draw some broad conclusions from observations of engineers who have worked, and are working with me.

Perhaps I can take a cue from an inquiry we recently received for a large straight edge. It was a routine request for an 180 inch straight edge except that it contained the startling clause "guaranteed not to sag." No suggestion as to how a straight edge can be prevented from deflecting. No comforting admission that .0005 or less, would be considered as good as no deflection. Not even a comment on the possibility of ever attaining the goal—just the blunt specification "Guaranteed not to sag."

I hope this was not one of your students serenely ignoring all you had taught him about the modulus of elasticity. Whoever it was, this inquiry has suggested that I might describe to you the end result we would like to see in a young engineer after you have finished teaching him. How to get him to this state; what to teach him, and how to teach it, are your problems. Like the non-sagging straight edge, it may even be that the end is impossible of attainment, but unlike the inquiry, we are willing to allow you a liberal working tolerance and won't insist on a guarantee of perfection.

Background for Proposals

Since my views on engineering have been developed from a life-long association with the machine tool industry, it might be well to speak briefly about this industry to give a little background to my views. The industry, although the backbone of this mechanical age, is a small one. Its plants are not set up with endless assembly lines and it produces in lots of 1 to 50 rather than in millions. Its engineers must be versatile—prepared to work on all the problems presented by a machine, and on the partially related problems of such different machine tools as Grinding Machines—Milling Machines, and Automatic Screw Machines. Single Machines or small lots or machines cannot carry the costs of exhaustive studies, and a machine tool designer is limited in the time he can devote

* Presented at the Mechanical Engineering Conference of the A.S.E.E., Minneapolis, June 18–21, 1947.

to his particular assignment. He must have a good knowledge of fundamentals and must use this knowledge in making many decisions where exact information is lacking. For example: a designer must recognize the points where stress concentration will exist—must know the design steps to reduce its effects, and yet may never know just what the stresses are in the case involved for the cost of lucite models and strain gage investigations can rarely be carried by a single machine tool order, although we are doing much along these lines on our standard machines.

Fundamentals—the Starting Point

With this background, our first demand is for young engineers with a thorough training in the fundamentals of engineering. Men who know their mathematics, physics, mechanics, strength of materials, and the theory of structures so well that they have confidence in their knowledge and when faced with a new problem, will fall back on this basic knowledge and begin their analysis from there. In our industry there are hundreds of problems and fields of design which are not covered in college courses. No engineering school has courses in milling cutter design and few students have heard about clearance, rake, and spiral angles. We do not think you should give courses in milling cutter design, but how are you going to prepare the young engineer who must take up this work? The surest way of helping him is to ground him in fundamentals. Make him so sure of his mechanics and force analysis that he won't get lost in the complex forces which act on cutter teeth. Ground him in the basic concepts of heat; the conversion of work to heat, and the flow of heat through a mass and from one medium to another. We can give him details and help him on from here, but best of all, with such a basic training he can go forward himself.

As we began a new program of applying electrical controls to machine tools we were faced with many problems in design. No College had ever considered these problems in their courses and in many cases the answers weren't known. The engineers assigned to the job were qualified only if they knew the fundamentals of engineering and were prepared to proceed from there.

A typical problem which bridged the fields of mechanical and electrical engineering was the design of a high-speed viscosity switch. In the operation of a milling machine there are some actions which must be controlled by the direction of motor rotation. For example: When a milling cut is completed, it is desired to reverse the direction of table motion and to return to the loading position at quick traverse speed. If the cut is a blind one, or one approaching a shoulder, it is imperative that the reversal precede the shift to quick traverse. If this sequence is upset the table jumping forward at quick traverse rate will jam the work into the cutter and cause a smash-up. To be certain the desired sequence of actions is never violated, a viscosity switch can be used and through it the direction of motor rotation can open and close control circuits. This was a simple solution except for the fact that there weren't any successful, high-speed viscosity switches. A few bulky, low-speed devices were on the market but nothing of small size that could be operated directly on a 3600 RPM motor shaft. No courses

electrical or mechanical, cover the design of viscosity switches; no text book discusses the principles of design, or ventures empirical rules. Faced with design problems of this type, an engineer must depend on his knowledge of engineering fundamentals. Backed up with the ability to calculate the viscous drag of an oil film and a knowledge of the generation and dissipation of heat and its influence on viscosity, an ingenious designer can work out an acceptable design. With a sketchy knowledge of fundamentals, a designer will have a discouraging record of tries and misses.

Hundreds of similar design problems can be found in our industry; Small Tool design, gear pump design, hydraulic motors, grinding machine spindles, high-speed chain drives, etc. You do not teach these subjects in school—it would be an impossibility to try to cover them. The only help you can give a young engineer who must work in these fields is to ground him in fundamentals. Repeat, emphasize, hammer away, at the fundamentals.

You know, I know, all good mechanics know, even some of your students know, that you can't slide a thin washer along a shaft by pushing at one point on its outer edge. The washer is self-locking, the fundamental analysis is simple and your students can probably draw the free body diagram. For all this I would still claim that you haven't done a thorough enough job of getting across the fundamental concepts. I can show you at least four variations of this problem where engineers have fallen into the self-locking or near self-locking trap. A V-plunger pushed by slow-moving table dogs, single shoe shifting forks moving splined clutches, short lands on intermittent gears, and small pinions journaled in large bearings. Give the problem some new clothes and the young engineer hasn't a firm enough grasp of the fundamentals of friction analysis to see trouble spots. We have spent hundreds of design hours and thousands of dollars planning and making corrections just because designers did not or could not draw free body diagrams and unknowingly let friction forces get out of line with applied forces.

I always hesitate a little when I get on the subject of friction for it suggests a group of our designers who were standing around a new machine looking at a mechanism which wouldn't work correctly. One designer was explaining that there was too great a difference between the static and kinetic friction coefficients and for that reason operation was erratic. An old-time mechanic who had assembled the machine rather bluntly interposed with "I don't think that's it." The designer, irritated, said "Why George I'll bet you don't know what static friction is." "Oh yes I do—that's what wears the seats out of the pants of the Engineering Department."

Rigidity

It is quite obvious to designers that parts must be so proportioned that they will not be overstressed by working loads. Designers are far less aware of the necessity of proportioning parts to control deflections which occur under these loads. In the machine tool industry more design decisions are based on rigidity than on strength. Because of this, I believe more attention should be paid to the analysis of deflection in machine design courses.

One of the first deflection problems in machine tools is described in the

book "English and American Tool Builders" by Professor Roe from which I quote the following:

"Watt had been working for several years on the steam engine when the idea of a separate condenser came to him on that famous Sunday afternoon walk on the Glasgow Green in the Spring of 1765. Watt was a skilled instrument maker and his first small model was fairly successful, but when he undertook 'the practice of mechanics in great' his skill and all the skill of those about him was incapable of boring satisfactorily a cylinder 6" in diameter and 2' long. For ten weary years he struggled to realize his plans in a full-sized engine. His chief difficulty lay in keeping the piston tight. Small wonder—for we find him complaining that in an 18" diameter cylinder at the worst place, the long diameter exceeded the short by ⅜ of an inch.

"Fortunately in 1774, John Wilkinson hit upon the idea of making the boring bar heavier, running it clear through the cylinder and giving it a fixed support at the outboard end."

With cutting tool deflection under control, it was possible to bore cylinders "almost without error" so that one of 50 inch diameter "did not err the thickness of an old shilling in any part."

The relationship between machine rigidity and accuracy of work suggested by Wilkinson's boring machine has been an important factor in every machine tool ever built. Modern machine tables or slides cannot be positioned with accuracies of .0001" unless table screws, screw thrust bearings, and supporting brackets are designed to deflect less than .0001. Machines cannot produce surfaces of fine finish with micro-inch readings below 10 unless wheel spindles and work supporting members have good rigidity and can keep their relative positions within this .00001 figure. Machines cannot produce work flat and square within fractions of thousandths unless machine ways can hold their alignments under shifting loads.

An engineer working on fine measurements or a designer working on small tools almost forgets the problem of strength and is instead forever concerned with the problem of rigidity. No one ever worries about whether a micrometer will break, whether a dial indicator post will snap, or whether a surface plate will be overloaded, but if any one of these deflects by .0001" it may be a failure worse than breakage. After all, there is something nice and positive about breakage, but a little error from deflection can quietly slip into your measurements and give you nervous exhaustion trying to reconcile repeated readings.

There is one specific deflection problem which I find generally ignored. That is the problem of the relative deflection of a journal and its bearings. Students will make lengthy calculations of load-carrying capacity, heating, location of oil inlets, and never suspect that deflection may make these calculations useless. Look at the hundreds of books and papers on plain bearing design and you will see that students are not alone when it comes to the neglect of deflection analysis.

We appreciate the problem when we consider the design of plain bearing grinding machine spindles. These bearings lubricated with water thin oil (32SSU) and operating with a radial oil space of .0001 to .0002, are very sensitive to deflection. The overhanging loads produced by the grinding wheel on one end of the spindle and the V belt drive at the other end, can easily give a spindle enough slope to make it touch, metal to metal, on opposite ends of a bearing. A student

impressed by the proportions usually shown for bearings or placing trust in the empirical rule that length should be two or three times the diameter, is likely to get into trouble.

If you would have your students earn more than an "old shilling" when they graduate, and if you would help us preserve for our machines the title "The Master Tools of Industry" then teach deflection analysis as rigorously as you teach stresses, and make your students as conscious of the problems of deflection as they are of breaking loads.

Unity

The second recommendation I would like to make is that Engineering Schools do a much more thorough job of integrating and coordinating their courses. The fundamentals of mechanics, physics, and strength of materials, should be more carefully traced through the advanced courses. Courses do not exist by themselves. They should show a strong thread of development from the fundamentals and should show the relationships between courses. In this way, the whole engineering program can be given some unity.

For more specific discussion we might consider a machine design course. It would be my suggestion that the course be set up to show how the fundamental courses, the basic tools of engineering, may be used in machine design. It should show a student how, by using force analysis, dynamics, strength of materials, etc., he can work out good designs. The course would not set up a new and different world with magic formulas and glimpses of practical know-how, and it would never be a haven for those students who sigh with relief that the theoretical and time-wasting courses in physics and mechanics are over. The course instead would show how the basic ideas covered in the earlier engineering courses, are the foundation of design. For all their complexity, gears are problems in uniform motion, the contact stresses of convex surfaces, the bending stresses of cantilevers and fatigue life under these stresses. Clutches and brakes are problems in friction, energy and heat, wear, and the nice force analysis of self-actuation. Ball and roller bearings are problems in stress and deflection and the basic principles of design hold true in all the many series that are offered.

This dependence on fundamentals can be found in all the subjects of design you teach. If you high light these fundamentals and show the strong thread of development from early courses through the design courses, you can give some unity to engineering education. A student would have a good chance to make practical use of the fundamental courses and would complete a design course with a clearer, surer knowledge of mechanics, physics, and strength of materials.

The coordination of courses and the broad application of basic ideas were called to my attention in a simple example. The reversing clutches on the spindles of automatic screw machines have been carefully studied and analyzed. We have understood the basic concept that in bringing a body up to speed with a friction clutch, you must waste in heat, an amount of energy equal to the kinetic energy which the body will have when it reaches top speed—that the energy lost in a complete reversal from full speed in one direction to the same speed in the opposite direction, is four times the kinetic energy of the body and that this is

twice as much lost energy as would be involved if the spindle could be braked to rest and then accelerated to speed. These relationships were also understood to hold regardless of whether clutch torque was large or small, constant, or variable.

Now in close work with our electrical engineer on the problem of the permissible frequency of table operation on a machine tool whose driving motor starts, stops, and reverses with the table, we were surprised to find him estimating motor heating with the same basic energy relationships. The energy lost in starting was equal to the final kinetic energy of the motor rotor and the connected members. One reversal was four times as bad from the point of view of heat as one start and one plugging to rest, stop was three times as bad as a start. This was talking our language and these were the basic relationships we had forced ourselves to recognize on screw machine spindles.

No college courses ever showed us these simple relationships. As far as college was concerned electric motor design and machine design were taught in different languages. I think both courses should have been hammering away on kinetics and developing basic ideas.

To encourage coordination of courses, I would go so far as to suggest that each Professor be asked to sit in as a student on at least one course a year just to let him see the similarities between the things he teaches and those being taught by others. Perhaps teachers would see why students spend so much time trying to make equations of inch-minutes and foot-seconds balance. Perhaps the machine design instructor could see a little closer relationship between the theory of structures and some of the deflection problems in machine design. Perhaps the mechanics Professor could make his own course more useful if he saw what a mechanics problem looked like when it gets all dressed up in the complexities of a civil engineering problem. It would do the electrical engineer much good to sit in on a physics course and learn that basic ideas got started long before the first patents were issued. And how we all would enjoy watching the physics professor trying to wring a few units with which he usually works. honest horsepower from the maze of

This is probably make-believe, but I do wish that men would begin to see the similarities between courses and become more aware of the fundamentals which carry through all courses. Students need greater unity in their Engineering Education.

When it comes to "sitting in" I would like to venture one more suggestion, and that is—that Instructors and Junior Professors be encouraged to spend some part of their Summer in industry, and that this engineering work be given the same status as Summer research or writing. I know there is a vast difference between practical problems and boow problems, and if you are to prepare men for industry, then you must know what is required and the best way to obtain this information is by practical experience.

Sometime ago this difference in relationship was brought out by an engineer in a simple illustration—of changing an automobile tire in the garage to changing a tire on a narrow, highly-crowned, soft-shouldered road on a rainy night. None the less the experience would be vivid and your teaching would be more interesting because of the experience. Someone aptly described a "minor operation" as "an

operation performed on somebody else." So it is with classroom examples. The fatigue break which you investigated can become a much more lively subject in class discussion than the impersonal textbook example and the beam of uniform strength you designed for a feeding finger can be a more convincing illustration of design analysis than the colorless skeletons usually cited in the handbook.

In order to prove that the student is getting all these fundamentals that are necessary for correct machine design, as well as to get him into the habit of looking up factual matters, I would suggest that you put more of your effort to teaching logical thinking, analytical methods of solution, and critical selection of the results. My suggestion to attain this is to prepare practical individual questions or problems for each student to work out, which to my mind will cultivate more original thinking and at the same time, prove whether or not your student has been well grounded in the fundamentals. I feel that this method will also prove your student's creative ability, which is one of the factors most essential in machine design. This I know I will take more time on the part of the Professor, in preparing his class work—it will also prove more laborious in correcting papers because of the fact that the student has more latitude in working out his problem, but I feel quite certain that this method will create more interest among your students outside of his classroom, as students will become interested in each other's problems. I definitely feel any student who is interested enough to take the machine design course must have a definite liking for this field and by giving them individual practical problems, is certain to keep their interest alive.

Breaking away from education but still thinking of unity and coordination, I have the opinion that one of the serious criticisms of our technical literature today, especially of the papers published by our large engineering societies, is that they do not show interrelationships. There is too much emphasis on the aspect that—this is new—different—a startling departure—a revolutionary development. I think the emphasis should be in the other direction of establishing similarities and showing how fundamental concepts have been used. The maze of material being presented these days needs simplification. I know of no better way of getting it than by making authors more conscious of the unity that exists in engineering subjects. I do not expect you to correct this bewildering condition for us and I have mentioned the problem solely to point out that we need more unity in our engineering thinking and that you can give students lasting help if you can give them a well coordinated or unified education.

To conclude this talk, I need only to warn you that if you teach a boy the design of punch presses, we shall probably put him to work on sewing machines. If you prepare him in internal combustion engines, we shall most likely ask him to lay out a centrifugal pump; and if you teach him electric generators, there is a good change he will spend his days trying to determine which millionth of an inch a strain gage is indicating. You can help these boys most if you ground them in the fundamentals and give them a unified knowledge of engineering.

If you work out such a program, let me know—I need the course myself.

Discussion on Mr. Graves' Paper

Prof. A. H. Burr, of Northwestern University: In design of a particular machine does not the student learn principles common to all machines? Should specific design problems be carried out in classrooms?

Mr. Graves: Yes. Fundamentals can be taught by means of interesting design projects. Probably simpler problems are better than long complicated ones to teach fundamentals effectively.

Prof. E. N. Baldwin, of Penn. State: Can you give us other specific cases of student pitfalls in application of fundamentals?

Mr. Graves: (Showed prints of gear problems, indexing mechanism, and bearing problems.)

Prof. W. J. King, Cornell: Is emphasis on appearance-design general in the machine tool field? Are texts available?

Mr. Graves: Brown & Sharpe has a small group of industrial designers working on appearance design of products. I know of no particular texts and those in existence are too specialized and individualistic in styling and often impractical. Functional requirements are paramount to appearance.

Prof. M. S. Gjesdahl, Penn. State: What proportion of time should be devoted to drafting practice in engineering curricula?

Mr. Graves: Not too much time as we can give adequate training in drawing and do not keep engineers on drafting work for more than a short period.

Prof. P. H. Hyland, Univ. of Wisc.: What can schools do to overcome student dislike for drafting? Do all companies move engineers through drafting rooms as fast as possible?

Mr. Graves: The companies of my acquaintance follow a policy similar to ours. Our engineering and drafting departments are separate and have no engineers on permanent drafting.

————: What do you do with young engineers who do not prove to have proper qualifications for advancement out of drafting?

Mr. Graves: We come to a definite understanding with such men and do not encourage them to remain with us if they cannot so advance? (We may move him into another division if he looks like good material, such as factory or sales.)

Prof. T. P. Colbert, of Bradley: Our schools have an industrial arts course. Should not such training be specifically an arts course and not pretend to be engineering?

Mr. Graves: Yes, the arts and engineering should not be confused but common fundamentals in either case should be stressed. The industrial designer needs to have an artistic viewpoint.

Prof. Bradley: Should we train tool designers in special courses?

Mr. Graves: No. My personal opinion is that no such special courses are necessary. I would place a graduate in tool engineering in the tooling department and his chances for advancement as an engineer would be slight.

Prof. H. K. Palmer, Univ. of Minn.: How far should we go in design details?

Mr. Graves: Stick to fundamentals.

Prof. Palmer: Won't lack of knowledge of details and detail drawings be a handicap to a boy?

Mr. Graves: I do not expect him to be an expert on details, or drafting,

only to have a sound command of fundamentals of engineering. We can readily teach him detailing and system.

PROF. BRADLEY: Kinematics instruction on the inversion of mechanisms stimulates creative thinking.

MR. GRAVES: I do not think this method stimulates creative thinking any more than other methods, and unless it is handled correctly, may become involved.

PROF. CAYWOOD, of Univ. of Iowa: Would you approve of any tool design course?

MR. GRAVES: No. A knowledge of mechanics is sufficient. Our tool designers are usually taken from the drafting room force. If we require a graduate engineer in our Tool Design Force, we can teach him if he has engineering fundamentals.

PROF. BALDWIN, of Penn. State: Have you any suggestions as to coordination of courses in materials properties?

MR. GRAVES: Each type of industry has its individual problems and metal specialists must handle this. Young engineers receive their training from these specialists, either direct or through their Chief Designer.

Mathematics in Civil Engineering

By JOHN M. HAYES

District Bridge Engineer, Little Rock, Ark.

The writer has always been interested in engineering education and was greatly attracted by two articles, which recently appeared in THE JOURNAL OF ENGINEERING EDUCATION—"Mathematics in Civil Engineering," by Harold E. Wessman, January, 1947, Vol. 37, and "Teaching Mathematics to Engineers," by L. E. Grinter, March, 1947, Vol. 37. He thought that possibly comments upon this subject by a civil engineering practitioner would be of interest to engineering educators, for whom he has the greatest of respect and admiration.

Mathematics is one of the most powerful tools that the engineer has at his disposal. It is fundamental in the development of the basic theory in any branch of engineering. It is inconceivable that any teacher of strictly engineering subjects should not realize the importance of a thorough grounding in pure mathematics, and with a fair degree of rigor too. Yet many do not seem to realize its importance. It is easier to understand why the average engineering practitioner belittles higher mathematics, and by higher mathematics, is meant anything above simple algebra, simple trigonometry, and simple analytic geometry. Most engineering students have completed their formal study of mathematics by the end of their sophomore year and very little mathematics, other than simple algebra and trigonometry, is used in conjunction with their junior and senior engineering studies. Possibly calculus is used to define the slope and deflection of a beam; but, from the amount of calculus that is used, many engineering students often doubt the necessity of its study. Most civil engineering students are, therefore, not very conversant with calculus and the higher reaches of algebra and trigonometry by the time they graduate. Many of them have not had the importance of mathematics pointed out to them by their engineering teachers. Then the positions that they hold for the first few years after graduation are usually of a routine nature and require only a knowledge of simple mathematical operations. At the end of this period these young engineers are beginning to become strangers with anything but these simple mathematical operations. By the time they are confronted with problems that could be solved more easily and quickly by the use of higher mathematics, they are indeed strangers with the subject. Instead of reviewing their mathematics, they belittle its importance and look with scorn and amusement upon anyone who is interested in the subject. It is surprising how many develop this viewpoint. They do not realize how much time can be saved

by the use of higher mathematics in the solution of many fairly commonplace problems, and they are lost for an exact solution of the more intricate ones. They are scared at the sight of an integral sign that appears in the literature published in the proceedings of their engineering societies and are prone to say, "who reads it anyway." To this group is gone the opportunity to delve into the fundamental theories of their profession. How could anyone get into the interesting fields of the theory of elasticity, the theory of elastic stability, or higher hydraulic theory without a partial understanding and appreciation of higher mathematics?

The problems encountered in the computation of quantities for engineering estimates are usually solved by the use of simple mathematics, but the use of higher mathematics would often result in a great saving of time. The series can be used to great advantage in the solution of many practical problems, but they are considered as higher mathematics and the average engineering practitioner is again lost in the use of this most valued tool. For instance consider a problem involving a horizontal cylinder partially full of water, where it is desired to develop a general equation for the varying water pressure acting circumferentially around the vessel. The easiest way is by the use of a Fourier series, but again this is higher mathematics.

What is the answer to this matter? With all of the talk about the broadening of engineering curricula, it is not easy to say. It is thought that mathematics should be taught by professional mathematicians who, as Professor Grinter points out, should impress upon the student the fact that mathematics is "a useful tool, in fact the most powerful of all scientific tools," and "would never let the engineering student forget that fact for a single moment." Such a teacher would cite practical applications whenever and as often as possible. He would gradually impress upon the student that he needs mathematics and that he can use it to his advantage. The writer agrees with Professor Wessman that each branch of mathematics should be taught as separate courses, as conventionally grouped, and not as scrambled unified courses. The engineering teachers should use mathematics in the development of the theories of their subjects and impress the student of its utilitarian value and the importance of its continuous review in order to keep a working knowledge of it at his finger tips. This is pointed out by Professor Wessman when he writes, "There is a value in overturning the mathematical tool kit occasionaly in order to get acquainted with the best tools for the various engineering problems which occur in practice." In passing it would be well to emphasize the obligation of the engineering teacher to frequently advise the student of the importance of continuous and further study of his engineering subjects and to impress him with the fact that the "commencement" at the end of formal undergraduate training means only that the graduate has a few tools with which to further his study. In design courses more emphasis should be put upon the mathematical development of the fundamental theories and the background of specification requirements rather than blindly designing some typical structure in accordance with the provisions of standard specifications.

It would be highly desirable, and of benefit to many civil engineering students, if a year of higher mathematics could be included in the undergraduate

curriculum. However, the conventional amount of mathematics now included in the undergraduate engineering curriculum will undoubtedly stay about as it is for some time, with higher mathematics left for self-study or graduate work. Mathematics is one of the hardest subjects for self-study that most engineers encounter, so the importance of formal study in this field cannot be over emphasized, at least, until the student is familiar with the elements of higher mathematics. It is hoped that the future civil engineer will be able to make more efficient use of his mathematical training.

Comments on Army ROTC Programs

By P. B. NARMORE

Executive Dean, Georgia School of Technology

Down south in Georgia we have a saying, "Whenever two or more Presbyterians get together they pass the collection plate." For many years a somewhat analogous saying is to the effect that everytime two or more educators get together they discuss curricular matters. Usually this discussion in the past has concerned itself with the amount of social studies in the engineering curriculum. Today we are extending the discussion to Naval and Military courses and their place in engineering education. A number of Army and Navy officers want this discussion to continue and I am sure many engineering educators do, also. We realize the necessity and value of ROTC training on the college level, but we want it to keep pace with the changing needs of both engineering education and military training.

For many months our Federal Government has been studying the need for Universal Military Training. I am of the opinion that more discussion will be necessary if this national training program is adopted.

To understand some of the problems in the ROTC program it is necessary to consider some statistics. The Army program plans for training 210,000 students each year in comparison to the 14,000 Navy students, or about fifteen times as many as the Navy will train. The Army has fifteen different types of units and curricula in the advanced ROTC program. The Navy has one main curriculum, differing only in the last three semesters in the curriculum for Marines. In checking the number of ROTC units, I find that the following numbers are either established in colleges now or will be by July 1, 1947.

Engineers	35
Field Artillery	32
Army Security	2
Quartermaster	23
Transportation	14
Armed Cavalry	11
Seacoast Artillery	2
Medical	23
Infantry	103
Signal Corps	37
Ordnance	22
Air Corps	77
Chemical Corps	6
Military Police	8
Anti-Aircraft Artillery	18

Some educators believe that these fifteen units with their highly specialized curricula are too many, except possibly during time of war. Some schools have so many units now that they have difficulty furnishing space for equipment. The need for classrooms is increased considerably by increasing the number of units at a school. Display space for equipment also is increased according to the number of units. Certain specialized equipment is required for each unit whether it has 100 or 500 students. As an ex-

ample of the large number of units at individual colleges, I find

Texas A & M	has 12 units
Ohio State	has 9 units
Univ. of Illinois	has 8 units
Univ. of California	has 8 units
Massachusetts Tech.	has 7 units
Georgia Tech.	has 7 units

Returning now to curricular matters, one question that has been discussed informally concerns the refusal of the Army and Navy to substitute college courses for similar ROTC courses even though the college courses are taught by men with better training for teaching the subject. As an example, many of our Georgia Tech boys study a course in psychology as well as a course in personnel management. These courses are taught by trained instructors most of whom have either their Ph.D. degree or have had professional work in the field. Even though the ROTC could select their officers, it is expecting too much of such an instructor to compete with a professional psychology instructor. Still the ROTC requires nearly all of our students to take a course called "Military Leadership, Psychology, and Personnel Management." The scope of this course is as follows: Principles of psychology; psychology in battle; morale; personal attributes and professional qualifications of the leader; pride; rewards; punishments; etc. Practically all of these topics are covered in our college psychology course.

Many college courses in electrical engineering, including electronics, could well be substituted for Signal Corps courses. Chemical engineering courses could substitute for Chemical Corps subjects; aeronautical engineering courses could substitute for Air Corps courses; civil engineering courses could substitute for Engineering Corps courses. Accredited colleges should be permitted to substitute practical experience and comparable college courses when approved by the PMS & T just as any other department head may accept courses for substitution. The policy of non-substitution continues on up into the ORC and I believe it to be unwise.

Please pardon a personal experience which will explain my point. In my undergraduate ROTC I had been assigned to the Signal Corps because my general engineering course consisted mainly of electrical and mechanical engineering. The major subject for my masters degree was civil engineering. My doctorate was in engineering mechanics with a research problem supported by the Timken Roller Bearing Co. I later taught theoretical mechanics and strength of materials for ten years. In the meantime I had lost all contact with anything connected with the Signal Corps. This theoretical and professional experience closely allied with ordnance was not considered sufficient to permit transfer from the Signal Corps to the Ordnance Corps. The Army insisted that it would be necessary to complete some twenty odd correspondence courses before transferring.

A subject of interest is found in the following table which gives a comparison between professional courses in quarter hours as taught at Georgia Tech and the military requirement of 30–36 credit hours.

Dept.	Total	Soph	Junior	Senior
A.E.	46		9	37
Chem. Engr.	48		13	35
C.E.	58	8	17	33
E.E.	62	3	28	31
M.E.	53	4	21	28

Is this large number of ROTC hours necessary when there is duplication especially when we consider the professional courses are a necessary preparation for earning a living?

The requirements for a commission at Georgia Tech are considerably more than the average person realizes. Our students have military duties for 160 hours each year or a total of 640 for four years. Allowing an additional hour for preparation, 1,280 hours are required for military. If we consider 40 hours as a week's work, then 32 weeks are required. Adding six weeks for the ROTC camp, the total is 38 weeks. If we had allowed two hours preparation for each of the 640 hours, we would account for an equivalent of 52 weeks of work.

The results of a study as to how 35 outstanding colleges allocate time for ROTC recitation and drill are given in the following table.

Elementary Course

3R	4 Colleges
1R2D	4 Colleges
2R1D	13 Colleges
2R2D	3 Colleges
3R1D	5 Colleges
3R2D	4 Colleges
2R3D	1 College
3R3D	1 College

Advanced Course

3R	1 College (courses other than Arty.)
3R2D	7 Colleges
5R	4 Colleges
4R1D	14 Colleges
4R2D	3 Colleges
5R1D	4 Colleges
5R3D	1 (Military College)

About 40 per cent of the colleges give more time in the elementary course than the minimum of three hours required by the Army. Less than 25 per cent of the colleges give more time in the advanced course than the 5 hours per week required by the Army.

Another question sometimes discussed: Is it necessary for men in the professional schools to spend so much time on the drill field? Marching was important back in the days when the Infantry was supreme and when marching was the main mode of transportation. That day has gone forever, under mobilized transportation needed for rapid troop movements of men. Still our boys drill two hours a week in the basic course and once or twice a week in the advanced course. Any "poise" or "understanding of handling men" which may have been gained in the past is now largely supplied by required college courses in Public Speaking and Psychology. The only apparent value gained by drilling is that trainees may learn the need for coordination in group movements. This might be better supplied by war games.

One item of concern to college administrators outside curricular considerations is the difference in the Army and Navy methods of accounting for equipment. This equipment is usually located in the same buildings with the officers and is used exclusively by them. The Navy consigns all of their government property, including uniforms, to the professor of Naval Science. The Army requires that the college appoint a military property custodian to receive and account for all Army property sent to the college. This responsibility includes handling uniforms. Furthermore, a bond is required of the college to indemnify the Army against loss of any of its property. Since the PMS & T uses the equipment and prepares inventories for his own use, nearly all colleges appoint him as their property custodian. Nearly all colleges pay the ROTC staff well for this service which the Army should do themselves. The practice of making

schools responsible should be done only where they fail to provide reasonable property security.

In conclusion, I am sure I voice the sentiment of all gathered here that colleges have a patriotic obligation to work continually for improvement in the ROTC programs. With this feeling I believe then, that we should discuss such points as:

1. Is it necessary or desirable to have the large number of specialized corps, such as three types of artillery, during peace time.
2. The possibility of substituting college courses for military courses on the same basis that other departments operate.
3. The necessity for the large number of hours required in the military program as compared to the number of hours in the professional courses.
4. The advisability of reducing the number of hours spent on the drill field.
5. The Army requirement that colleges act as property custodians of military uniforms and equipment.

The Humanistic-Social Studies in an Engineering Education: Some Basic Fallacies

By MELVIN KRANZBERG
Amherst College

In an age of accelerated technological development it might be expected that attention would be paid only to education along technical lines and that studies dealing with man's social relationships and cultural expression would be slighted. Instead we find that even in those institutions dedicated primarily to the production of engineering specialists greater importance is being attached to the humanistic and social studies than ever before. The civic and professional responsibilities of the engineer are constantly stressed, and it has become a commonplace of commencement oratory to point out that the engineer is a citizen as well as a man trained to a high level of technical competence in a specialized field. The role of the humanistic-social studies is emphasized as giving the student that broad and liberal viewpoint, embodying some measure of social consciousness, which will encourage him to perform his duty to the community in all spheres of activity rather than only in the narrow one wherein his engineering ability is applied.

This realization of the part which the engineer must play in the modern world is, fortunately, not confined only to the speakers on the commencement platform. The engineering schools themselves have become increasingly conscious of this fact; their attempt to make it one of their primary objectives—in addition to the giving of an engineering education in the limited sense—is responsible for the enlarged interest in the humanistic-social studies manifested by the changes in curricula and by the large number of articles in the JOURNAL OF ENGINEERING EDUCATION dealing with that subject.

Despite the almost complete unanimity on the aim of converting the engineer into a well-rounded man rather than a narrow specialist and the need for the humanistic-social studies to achieve that end,[1] there exists no general agreement as to how these studies are to be employed to achieve the desired result. Some educators would teach non-technical subjects as they are taught in liberal arts colleges, maintaining that these essentials could be learned only if they are taught in their pristine purity, unsullied by any concessions to the special needs of an engineering student.[2] Others would make

[1] There are exceptions to this "unanimity." Cf. S. F. Borg, "Humanistic-Social Studies in Engineering—Another Viewpoint," *Journal of Engineering Education*, Vol. 36, March, 1946, pp. 424–425.

[2] Alfred C. Ames, "Should Humanistic-Social Study Be Made Engineering Education?" *Journal of Engineering Education*, Vol. 36, May, 1946, pp. 543–546.

the humanistic-social studies an integral part of the engineering curriculum by using engineering knowledge, tools, and ways of thought in those courses. In other words, they would use the non-technical fields of study to emphasize the attitudes and methods of thought which are a prerequisite for the strictly technical courses, while at the same time devoting them to subject matter of intrinsic value to engineers.[3]

It is unfortunate that, while decrying the specialization and compartmentalization of knowledge, these experts, by their emphasis either on keeping the humanistic-social studies separate from an engineering education or by intertwining them with such an education, have in most cases based their arguments on fallacious assumptions which presuppose the continued fragmentation of the fields of human endeavor. Even those specialists who realize that the humanistic-social studies, aside from the knowledge which they can impart concerning the world in which we live, can be used to inculcate the inductive approach and methods in solving problems which are employed in the engineering field, still relapse into the same errors against which they inveigh. They make a distinction between mathematical and "non-mathematical thinking" at the very moment they are trying to show that the humanistic-social studies can be used to reenforce and reproduce scientific thought.[4]

The fact is that our faculties of humanities and social sciences, as well as our technical professors, have allowed themselves to be "side-tracked" in their thinking on the question of the places of the humanistic-social studies in the engineering curriculum by preserving two concepts which have been outmoded for some time but which still maintain their hold on the popular mind and, evidently, on the minds of those who are attempting to integrate the sciences and liberal arts. These two traditional yet misleading concepts are those of the "scientific method" and the "scientific mind."

The engineers, the "applied" scientists, along with their blood-brothers, the "pure" scientists, have proudly claimed to be the sole possessors of a method which alone can perceive and pursue the truth, the so-called "scientific method." On the basis of this claim, our entire educational system, not only in engineering schools, has been broken up into segments based upon whether or not a certain method is supposedly applicable to a field of study. Furthermore, the non-scientific groups have been so intimidated by the engineer's mystical assumption of sole title to a method for the solution of problems that they have hesitated to employ the methods of the scientist. If the expert in the social studies ventures to use the techniques of the scientist, he apologizes for his seeming encroachment upon the sacred preserves of science. Quite unjustifiably he regards himself as an interloper or trespasser.

Actually, the so-called "scientific method" involves nothing more than the observation and collection of data, and its integration and interpretation on the basis of the perceived facts. There is no reason why this method and its basic attitude of detachment and objectivity should be considered the

[3] Elliott Dunlap Smith, "Can Humanistic-Social Study Be Made Engineering Education?" *Journal of Engineering Education*, Vol. 36, October, 1945, pp. 134–138.

[4] B. R. Teare, Jr., "Planning the Professional Aspect of the Humanistic-Social Courses," *Journal of Engineering Education*, Vol. 37, December, 1946, pp. 344–352.

exclusive property of the sciences. Other fields of knowledge can and have employed these methods and attitudes, as contributors to the JOURNAL OF ENGINEERING EDUCATION have pointed out in the past.[5] True, in the matter of human relations, the observation and collection of the data is made more difficult because of the lack of exact knowledge in some cases, the impracticability of precise measurements of social phenomena, and also because of the impossibility of repeating experiments insofar as historical events are concerned. But the fundamentals of the "scientific method" and attitude are applicable to all fields of human endeavor as well as to those which deal with the physical aspects of matter.

The concept of the "scientific mind" is another fallacy which has hampered the integration of the humanistic-social studies into the engineering curriculum. The implication of this concept is that engineers are people apart, possessing certain mental qualifications enabling them to deal with esoteric problems regarding the nature of the physical universe, but leaving them totally unqualified to deal with matters of an esthetic or social nature. Like all good geometrical theorems, this proposition has a converse, namely, that there are certain other people who do not possess a "scientific mind" and hence are incapable of understanding the problems and work of the engineers. The results of this distinction between the scientists and non-scientists can be seen in our entire American educational system, but nowhere are they more apparent than in the engineering schools, wherein this difference is employed to explain the shortcomings of both faculty and students. Thus the possession or lack of the "scientific mind" is advanced to explain the failure of the student who excels in physics to be able to write a simple English sentence properly, while the students assume—as do some of their colleagues —that the professors of literature are unable to add the balance in their checkbooks correctly.

This idea of the "scientific mind" is based on the false psychological assumption that there are various faculties existing in the mind which enable some people to do problems of a mathematical or scientific nature without difficulty, while others who have specialized in other fields are unable to add two and two. Not only have psychologists been unable to discover any separate portion of the brain devoted exclusively to items of a scientific nature, but it is questionable whether there are any differences in the mental processes involved in the solution of a physical equation or a problem of contemporary social relations.

In all cases, whether dealing with physical or social phenomena, our minds work with symbols to make known our ideas. In the case of the mathematician the symbols are numbers; with the physicist they are numbers and Greek letters which have been assigned an arbitrary value or meaning; with the chemist they are literal and numerical symbols; in the humanities and social studies, the symbols are words. In each case, the symbols are used to express ideas. Unfortunately, in the humanistic-social studies we are forced to use symbols which are used in everyday life and which have received no artificially designated value upon which there is complete agreement, such as, for example, the value of Pi to the mathematician. But that does not mean that the mental processes involved in expressing ideas

[5] *E.g.*, Ames, *loc. cit.*

through symbolic terms are any different for the physicist than for the student of the humanistic-social studies. Yet the engineering student often claims that he is unable to express a clear idea upon politics because of this supposedly inherent psychological distinction, even though we now know that a high level of general intelligence is usually a prerequisite for excellence in any branch of knowledge and that any special attitudes which one might possess in certain areas of mental endeavor would be attributable to environmental or social factors rather than inborn psychological characteristics.

If the false distinctions between those possessed of the "scientific method" and the "scientific mind" and those who lack these essentials are obliterated from our thinking about engineering education, we may begin to reconsider the whole problem of the place of the humanistic-social studies in the curriculum. When we have purged our minds of these traditional yet fallacious assumptions we may proceed to reexamine the philosophical bases of our educational thought in the light of the unity of all fields of knowledge.

Attempts have already been made in that direction, to one of which has been applied the name "Scientific Humanism," [6] implying that there are no basic differences in the aims of the scientific and humanistic aspects of an engineering education. With the realization that the ends to be attained are the same for both elements of the curriculum, it should be possible to achieve an integration of the humanistic-social studies with the technical aspects of the engineering course that will satisfy the need for the production of an intelligent citizen without at the same time sacrificing the technical competence necessary for the engineer to perform his special work usefully to society.

[6] Edwin S. Burdell, "The Philosophy of Humanistic-Social Studies in Engineering Education," *Journal of Engineering Education*, Vol. 37, April, 1947, pp. 593–600.

Engineering Applications of Newton's Method of Approximation

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In computing deflections in diaphragms under various loading conditions, it is necessary to solve equations of the third degree. Solution by trial and error or by Cardan's Method of Substitution is so laborious and time-consuming that it is not convenient in cases where large numbers of equations must be solved. A more satisfactory procedure is to use Newton's Method of Approximation which in theory has been known for centuries but which in practice has been too often neglected. Newton's method provides a simple, rapid means for solving general equations of the nth degree with sufficient accuracy for the most exacting engineering analysis.

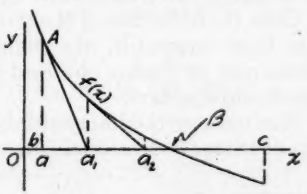


FIG. 1

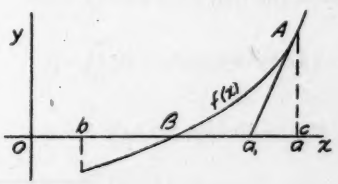


FIG. 2

In mathematical terminology, Newton's method may be tersely stated. If $f(x)=0$ within the limits b and c such that $f(b)$ and $f(c)$ have opposite signs, and if between b and c, $f'(x)$ and $f''(x)$ are continuous and $\neq 0$, then between b and c, $f(x)$ has but one real root β which may be determined to any degree of accuracy by Newton's method. Because of the conditions which are requisite for the application of Newton's method, $f(x)$ must plot like the curves shown in Fig. 1 or 2 or like those symmetrical with them about the Ox axis.

Referring to Figs. 1 and 2, the equation of tangent at A is

$$\frac{y-f(a)}{x-a}=f'(a) \text{ or } y-f(a)=f'(a)(x-a).$$

a_1 may be found by setting $y=0$;

$$\therefore \quad x=a_1=a-\frac{f(a)}{f'(a)}.$$

Then using a_1 as we have just used a, we get a closer approximation a_2 so that

$$a_2=a_1-\frac{f(a_1)}{f'(a_1)}.$$

As n increases, a_n approaches β.

The utility and versatility of Newton's Method can best be illustrated by a few practical applications.

In calculating diaphragm stresses, *i.e.*, tensile stresses resulting from flexure and direct tension (which occur when the deflection of a thin plate exceeds about one half its thickness), it is necessary first to determine the deflection y. For the particular case of a circular plate uniformly loaded with edges simply supported, y must be obtained from the following expression:

$$\frac{wa^4}{Et^4}=\frac{64}{63(1-v)}\left(\frac{y}{t}\right)+0.376\left(\frac{y}{t}\right)^3,$$

where w = Uniform load in pounds per square inch,
a = Radius of plate,
t = Thickness of plate,
E = Modulus of elasticity in pounds per square inch,
v = Poisson's ratio,
y = Maximum deflection.

If w, a, E, t, and v are known, this equation can be reduced to the form

$$my^3+ny+k=0.$$

Consider the following specific equation:

$$f(y)=13.56y^3+0.643y-.0115=0.$$

Then

$$f'(y)=40.68y^2+0.643.$$

As a first approximation of root, let $y=.05$;

$$\therefore f(y)=.1694\times10^{-2}+3.215\times10^{-2}-5.82\times10^{-2},$$

$$f(y)=-.0244,$$

$$f'(y)=.1017+0.643=0.745.$$

A closer value of the root is y_1:

$$y_1=y-\frac{f(y)}{f'(y)}=.05+\frac{.0244}{.745}=.05+.0314;$$

$$\therefore y_1=.0814.$$

Applying Newton's Method again to obtain a more accurate value of the root y_2,

$$f(y_1)=.732\times10^{-2}+5.23\times10^{-2}-5.82\times10^{-2},$$

$$f(y_1)=.0014,$$

$$f'(y_1)=.269+.643=.912,$$

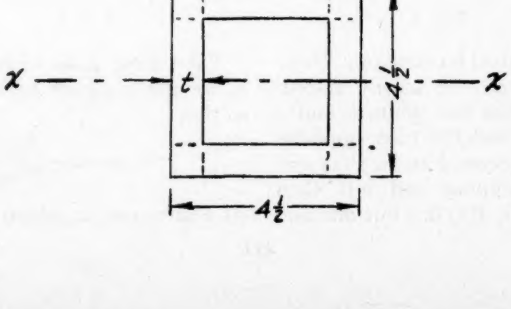
$$y_2=y_1-\frac{f(y_1)}{f'(y_1)},$$

$$y_2=.0814-\frac{.0014}{.912}=.0799.$$

This value of the root, obtained from only two applications of Newton's method, satisfies the original equation to three significant figures.

Once the deflection of the thin plate has been computed, the diaphragm stress may be readily obtained from a quadratic equation.

Newton's method may also be used to advantage in determining the thick-



ness of a hollow rectangular beam with given outside dimensions to satisfy a required moment of inertia.

For the section shown, the moment of inertia about the $x-x$ axis may be stated as a function of the wall thickness t, neglecting the corners.

$$I=-2.33t^4+20.25t^3-72.4t^2+60.74t=3.9,$$

where 3.9 is the required value of I;

$$\therefore\ f(t)=-2.33t^4+20.25t^3-72.4t^2+60.74t-3.9$$

and

$$f'(t)=-9.32t^3+60.75t^2-144.8t+60.74.$$

Try 0.1 as a first approximation of the root:

$$f(.1)=-.000233+.02025-.724+6.074-3.9;$$

$$\therefore\ f(.1)=1.47,$$

$$f'(.1)=-.00932+.6075-14.48+60.74,$$

$$f'(.1)=46.86;$$

$$\therefore\ t_1=.1-\frac{1.47}{46.86}=.1-.0312=.07.$$

Applying Newton's method again,

$$f(.07)=+.007-.355+4.252-3.9;$$

$$\therefore\ f(.07)=.004,$$

$$f'(.07)=+.298-10.136+60.74,$$

$$f'(.07)=50.90;$$

$$\therefore\ t_2=t_1-\frac{f(t_1)}{f'(t_1)}=.07-\frac{.004}{50.9}=.0700.$$

Another convenient application of this method is to be found in calculating the nth root of an irrational number with the aid of a computing machine. To find the nth root of p, we must solve

$$f(x)=x^n-p=0.$$

Then

$$f'(x)=n(x)^{n-1}.$$

As a first approximation, try a,

$$f(a)=a^n-p,$$
$$f'(a)=n(a)^{n-1}.$$

Then a_1, an improved value of the root, will equal

$$a-\frac{f(a)}{f'(a)},$$

$$a_1=a-\frac{a^n-p}{na^{n-1}},$$

$$a_1=\frac{1}{n}\left(an-\frac{a^n}{a^{n-1}}+\frac{p}{a^{n-1}}\right),$$

$$a_1=\frac{1}{n}\left(an-a+\frac{p}{a^{n-1}}\right),$$

$$a_1=\frac{1}{n}\left[(n-1)a+\frac{p}{a^{n-1}}\right],$$

where a = An approximate root,
a_1 = An improved value of root,
p = Any irrational number,
n = Required root.

For example, to find the cube root of 10, try 2.15 as a first approximation. This value was obtained from a slide rule which can be used to advantage in estimating square and cube roots. However, a less accurate value of the root could have been selected.

Therefore

$$p=10,$$
$$n=3,$$
$$a=2.15,$$

$$a_1=\frac{1}{n}\left[(n-1)a+\frac{p}{a^{n-1}}\right],$$

$$a_1=\frac{1}{3}\left[2\times2.15+\frac{10}{2.15^2}\right],$$

$$a_1=\frac{1}{3}\left(4.30+\frac{10}{4.6225}\right),$$

$$a_1=\frac{1}{3}(4.30+2.16333)=\frac{1}{3}(6.46333),$$

$$a_1=2.1544.$$

Checking

$$a_1^3 = 2.1544^3 = 9.9995.$$

Thus with only one application of Newton's method, an accurate root was found. This method is practical when a computing machine is available to check solutions by logarithms or to give greater accuracy than the number of places in the tabulated logs.

Other functions such as those involving e^x can be readily solved by Newton's Method of Approximation. However, enough examples have been given to show the 20th century usefulness of this 17th century discovery.

References

Fine, J. B. "Calculus"—John Wiley & Sons.
Roark, R. J. "Formulas for Stress and Strain"—McGraw-Hill Book Company.

Panel Discussion on Laboratory for Mechanical Engineers, Advanced Mechanical Engineering Laboratories

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Introduction

Laboratories for engineering students include studies of tests of materials, usage of chemical equipment, studies of fundamental principles in physics, and the functions and operations of machinery such as steam, internal combustion, refrigeration and other types of engines and shop machinery and machining techniques. In the Junior Mechanical Engineering Laboratories, various fundamental tests include measurements of oils, operation of engines, fundamental applications of control equipment and operation and study of basic machines utilized in steam, water and gas power production.

It has occurred to me that many of the basic principles involved in this earlier study of unrelated characteristics may be combined in more advanced laboratories in such a way that these principles may be subconsciously reviewed and more thoroughly understood. The application to unique combinations of equipment and their functions gives a meaning to the fundamental principles as determined by the projection of the individual into the development of the more advanced tests. An advanced laboratory of this nature would not only include earlier laboratory functions but would also review basic mechanics, physics, and many of the principles taught in the earlier courses where there has been less direct correlation with their application. An attempt to include generally the review and reevaluation of basic courses has been invoked in the development of the Machine Design Laboratory at the University of Minnesota, which may be used here as an example. In this laboratory specific fields of advanced machine design analysis of a complex nature have been set up to develop and accentuate ability of the student to utilize previous training in classroom or laboratory form in the solution and determination of factors which result in the more complex utilization of equipment. In the following discussion: (1) various types of laboratory problems will be briefly presented, leading to the correlation and advancement of previously obtained knowledge, and (2) general comments will be made with respect to this approach to engineering training.

I. Types of Advanced Laboratory Problems

A. Theory of Lubrication

The study of lubrication is sufficiently broad to warrant consideration by all Mechanical En-

gineering students. The hydrodynamic theory of lubrication is considered in the design of bearings and is given thought in the operation of all moving equipment in the various laboratories. Such a study involves the review of advanced mathematics, dynamics, hydrodynamics, and physics of fluids, applications of the study of the characteristics of lubricants, and the general design problems encountered in the operation of journals and bearings.

In the laboratories, a large shaft loaded with partial bearings on the top and bottom allows a brief study of the characteristics of speed, pressure, temperature, viscosity, clearances, power requirements, surface conditions, materials of shaft and bearing, methods of measuring temperatures, quantities of flow of lubricant and any other factors to be considered in the application of the hydrodynamic theory of lubrication.

B. Theory of Vibration.

A study of vibration characteristics opens a very broad field for fundamental analysis. Vibration in machines may be eliminated by proper design, by balancing procedures, by analysis with instruments, and by modification of the elements after construction. Conditions of vibration may be studied by the use of models, by tests with balancing machines, by a study of machine functions through analysis of noise with respect to frequencies and amplitudes, and by use of vibration instruments of recording and indicating types.

Familiarity of a student with this equipment and a study of the characteristics exhibited by these machines and instruments require a review of mathematical equations, theories of statics and dynamics, application of balancing weights, measurement of stresses, frequencies and amplitudes, and bring the student into contact with the practical aspects of the experiences he may entertain in the field of engineering, either by direct contact or association.

C. Theory of Photoelasticity

The study of stress analysis by photoelasticity makes possible a physical picture of the internal mechanism of stresses and an opportunity to view and understand the stress phenomena which he has previously observed in textbook, lecture, and laboratory form. The photoelastic polariscope breaks up polarized light into two components which are changed in velocity by stresses in such a way that interference bands indicate stress distribution in doubly-refracting materials. Thus, an application of the theory of optics is given, the effects of wave lengths with respect to color in light, the opportunity for developing laboratory technique of the operator, the necessity for perfect alignment of the lenses and prisms, the use of filters, and various light sources, the study of complex stresses and their analysis by mathematical equations and the final presentation in the form of an individual report, including an analysis of data, graphs, and conlusions obtained presents a very broad application of much of the required knowledge with many application procedures on the part of the student.

II. General Comments on Laboratory Problems

A. Equipment

The type of equipment for Advanced Engineering Laboratory suggested here is preferably not a finished machine with commercial controls and completely enclosed elements. It is funadmental in nature, basic in construction, and modified for ease of attachment of measuring instruments, and indicating devices. This equipment is not established for any particular course or research problem, but should harbor a number of fundamental elements which may be rapidly visualized and understood. In the preceding part, the discussion of lubrication, vibration, and photoelasticity equipment includes part of a set of laboratory experiments which consume approximately ten hours of lecture and thirty hours of laboratory. In a similar manner, it is suggested that broad fields in the division of Mechanical Engineering may be considered which are capable of sufficiently complex analysis to warrant advanced study of fundamental elements.

B. Test and Calculations

The student participation in the use of this equipment involves a study of the functions and a setup of necessary tools and instruments to obtain the analysis he desires. Some improvising should be necessary in the assembling of the equipment and a choice of methods of operation and test should be obvious. Some students may wish to make a more complex system; others may be content to do the minimum work necessary. As the tests proceed, they should be of such a nature that check calculations can be prepared and it is desirable that the final results may be checked against theoretical calculations. It should be possible to complete work on an individual set of problems during the laboratory period. Aids such as setting up data sheets and indicating the specific information needed will enable the student to understand more quickly the outline of the project and guide him in obtaining the necessary data. Sketches and calculation sheets are required and the specific data and the answers are to be shown on the data sheet. Percentages of error in the final results and the reasons thereof may be requested of a student.

C. Student Response

It is believed that the more advanced projects which tax the student's ability to think and act are preferred in this type of laboratory. In this manner, his interest is very intense throughout the entire project. If his initiative and understanding indicate that additional steps and calculations will obtain a greater amount of knowledge from the experiment, a student will strive for this result. In the assembly and set-up of the equipment and test instruments, the student becomes familiar with the use of wrenches, screw-drivers, standard connections and other equipment, and participates in the actual operation and test of the equipment. He has a better understanding of laboratory techniques, and although his skill is

not greatly increased, he develops an evaluation of information obtained by tests, the activities and procedures necessary to operate tests, and considerable responsibility in the performance of tests.

Conclusions

What may be the central theme of this discussion is the fact that all Mechanical Engineering students should be allowed to participate in advanced laboratories with sufficient complexity and personal responsibility as part of their student training. It is particularly important that students be allowed the opportunity of having experience, under controlled direction, wherein they are required to think and act with independence and assurance. Incidentally, they learn what a sine curve is as applied to the machine and the physical application of the logarithmic damping function.

Thus, the Advanced Engineering Laboratory in Mechanical Engineering should be one in which the student has considerable freedom to understand and evaluate a great number of the fundamental ideas which have been supplied to him during his course work in engineering.

Training for Research*

By ERIC A. WALKER

The Pennsylvania State College

The most obvious reasons for training engineers for positions in research are that there is an acute demand for engineers and scientists with such training and that a good fraction of our better students wish to acquire such training while still in school. This is not new, and there has been a growing trend in this direction for years. A recent study [1, 2] shows that about 6 per cent of the electrical engineers who are from fifteen to twenty years out of college are now engaged in research. This is not a large percentage of the whole. However, one out of five electrical engineers in the same age group is engaged in administrative activities. Undoubtedly some of these men graduated to such positions from careers in research and development. There are many other engineers who are classified as development engineers who might well be called research engineers. The same study shows that about 9 per cent of the same age group can be placed in this classification.

The trend toward research and development is growing, and it might be safe to estimate that one out of five of our electrical engineering graduates becomes a research engineer or scientist for part of his useful life. The line of demarcation is not a hard-and-fast one. Many development engineers and design engineers spend an appreciable fraction of their time on research. Every such engineer has found that when he starts to pioneer or even to create a design a little out of the ordinary, he is confronted with a lack of fundamental knowledge which must be obtained before the design can continue in an orderly and logical manner. He therefore has to stop his design engineering and indulge in a little applied research and thus, for the time being at least, he becomes a research engineer. Actually, the number of engineers who today are going into research is much greater than it has been in the past. Consider Table I, which gives some study of the growth of the number of research institutions, the number of research scientists, and the amount of money spent on research. In this table the national income is given as a baseline against which the dollar value of research should be measured. It is probably true that the money spent on research reached a peak during the war years. This situation was forced by the rapid development of government agencies interested in research, such as the Office of Scientific Research and Development, the National Defense Research Committee, etc.

* Presented at the Educational Methods Section, A.S.E.E., Minneapolis, June 18–21, 1947.

[1] "Employment Histories of Engineering Graduates," E. D. Howe, *Journal of Engineering Education*, Vol. 37, No. 7, p. 513.

[2] "A Re-examination of the Compton Report," H. H. Armsby, *Journal of Engineering Education*, Vol. 37, No. 9, p. 675.

TABLE I

Year	Number of Industrial Research Laboratories	National Income $	Funds for Industrial Research $	Funds for Government Research $
1920	300	74.10^9	29.10^6	15.10^6
1930	—	77.10^9	116.10^6	24.10^6
1940	2200	77.10^9	234.10^6	69.10^6
1944	2500	160.10^9	300.10^6(?)	719.10^6

Undoubtedly we are now in a period when many of the research scientists are returning to their pre-war jobs in teaching, production, and even in fundamental scientific work. There will be another reduction in the number of research engineers when the country's economic system falters once again and we have an economic depression. Nevertheless, the relative growth of research is permanent. No longer is research confined to the few large companies which can afford such a luxury, but research has become a necessity for the smaller companies which wish to insure their economic survival. It is true that research is not understood by many of those who feel it is a necessity, but it has become as necessary as insurance, and company A must have some research if only because its competitors have it and its competitors seem to do all right.

Since it is an established fact that the number of scientists engaged in research is rapidly growing, one might examine the engineer's place in this growth to determine if an engineering training is satisfactory for a career in research. There is considerable evidence that such training is not as good as it should be. This quality is not easy to measure, but some arbitrary yardsticks can be chosen. For instance, one might make a count of a number of scientists engaged in research and development and then determine what percentage was trained as engineers. As an example, if one lists the men who are prominent in the National Defense Research Council and defines *prominent* by saying they were listed as members of the division committees, one finds in a group of eighty-six such men thirty-six physicists and only seventeen engineers. Of this latter number, nine were electrical engineers, and the remainder were scattered among other branches.

Another measure might be the number of scientists employed by the directors of war research laboratories. Again it can be shown that a much larger percentage of these are physicists than engineers. One laboratory in particular hired five men trained as physicists for every one trained as an engineer.[3] As a matter of fact, at least one scientist went on record as saying that he favored the hiring of physicists because "the physicists showed more imagination."

Whether or not this rather offhand analysis is defensible is beside the point, but many laboratory administrators will admit that the physicists not only showed more imagination but had a wider knowledge. They knew more ways of filling a given need than did the engineers, and their analytical ability in many cases was quite superior. Lastly, because they had never learned any design formulas or knew anything

[3] "Roster of All Employees, Underwater Sound Laboratory, Harvard University, 1941–1946."

of the traditions behind standard designs, they were less inhibited and, although their mistakes were many, their successes were many and startling. These are facts, and using them as a basis, we might re-examine the qualifications of a good research scientist and see if our engineers can fill the specifications. If they do not, we might see how we can modify our training so that they do.

Some of the requirements for a research scientist are quite easy to list, although one might have difficulty in arranging them in order of their importance.

First, a scientist must have an analytical and inquiring mind. He must want to know what makes things tick and must want to understand the fundamental laws governing the action of any system or physical phenomenon.

Second, he must have considerable facility with mathematical principles and reasoning. He should want to explain the physical laws in terms of simple mathematical symbols which clearly and concisely contain all the facts necessary to predict the behavior of a system under different circumstances.

Third, he must be familiar with the ordinary physical concepts and the reasoning behind them. For instance, there should be no ambiguity in the scientist's mind when one tries to discuss with him an electric field consisting of flux lines and equipotentials. He should be able to visualize the mechanical considerations which govern the period of vibration of an oscillating system and should clearly understand those properties which can change the vibration characteristics.

Fourth, he must be familiar with the experimental method. This means he should have a certain amount of manual dexterity so he can set up apparatus with which to make fundamental measurements; but more important than merely making the measurements, he must be capable of posing the crucial question. By this we mean he must be able to state his theory so that it can be tested and proved valid by a set of physical measurements.

Fifth, it goes almost without saying that a scientist must have the intellectual integrity to lean completely and impartially on the data. He must not allow himself, by wishful thinking, to interpret the data in any dubious manner and thus lead himself astray and prove correct theories which are dubious or definitely false.[4]

Lastly in this brief analysis, the scientist must have the ability to express himself. There are three ways of doing this: by graphs and drawings, by mathematical symbols, and by expository writing. Obviously, it is of little avail for a scientist to arrive at a new theory if he cannot explain it to his colleagues and to the development and design engineers who must ultimately translate the theory into mechanisms for the public good.

In summary, then, the scientist or research engineer must have an inquiring mind; must be capable of handling mathematical and physical concepts; must be familiar with the experimental method; and must be capable of expressing himself.

If our regular four-year college course is not properly training engineers to become research scientists, we

[4] In an excellent paper entitled "Selection and Training of Students for Industrial Research," Dr. A. W. Hull lists the following characteristics: (1) character, (2) aptitude, (3) attitude, (4) knowledge. Of these Dr. Hull contends that character is the most important, and under character he lists *positive* honesty as absolutely essential. Cf. A. W. Hull, *Science*, Vol. 101, No. 2616, p. 157.

should try to ascertain the reasons and make the proper corrections. The first impulse is to attack the curriculum and to suggest the addition of new and different courses. Many will say the curriculum itself should be extended to five, six, or even seven years. However, leaving this argument aside, we might examine the matter to see if things can be improved without extending the allotted time.

First of all, do we know if our selection of students as embryo engineers or research scientists is good? Obviously, this must have something to do with the matter, for when a student comes to us, he has had eighteen years of training and has certain traits and capacities which he has inherited. Some measure of his ability to become a researcher should be found. This is doubly difficult, since although we are able to enumerate, in qualitative manner, those qualities which are sought in a scientist, we are not certain that these are the qualities which make a scientist a good one. If they are, we have no way of measuring them except by observing those scientists who have proved successful. Therefore, it seems that one of the first things we must do is to find some measure of a good scientist and then test our students to see if they have this scientific aptitude. This is a two-prong program which cannot be accomplished in a short time, but it is a program which well might be taken under advisement by the Committee on Educational Methods. Only after accomplishing this initial step will we be in a position to examine fruitfully our teaching and curricula.

There is always an urge to add certain specific courses to remedy specific ills; yet one must remember that good research engineers are trained in all of the curricula: aeronautical, mechanical, electrical, and chemical engineering. It seems fairly obvious that it is not so much the specific training that one receives as the type and breadth of training. To insure the necessary breadth, courses must be added which are not in the specific science covered by a certain specific curriculum. Many electrical engineers are quite deficient in thermodynamics and should have more thorough grounding in that science. The study of thermodynamics is not to be confused with the study of power plants or internal combustion engines, but it should emphasize the theoretical bases of that science. In a similar manner, the electrical engineer usually needs more aero- and hydromechanics. It is true that many electrical engineering courses include a course in hydraulics, while in others the course is omitted because most such courses are limited to the study of empirical formulas on weirs and simple static analyses. With such treatment, the course falls into ill repute and eventually is removed from the curriculum in disgrace.

The same sort of analysis may apply to curricula in other branches of engineering. Unfortunately, all such remedies presuppose the addition of material to the already overcrowded calendar, and therefore one must seek to remove courses to save time and to improve the overall efficiency. Again only loose generalities can be offered. One must remove all material which has transitory value only and concentrate on the enduring truths of science. The descriptive courses which tend to explain how a gadget works and how it is made can readily be scrapped and should be, since that gadget may not exist ten years from now, and if it does, it certainly will not be made in the same way. The "how-to-do-it" courses

and courses in manual arts will have to be eliminated, for valuable as such skills are, they must be relegated to the position of other self-taught attainments

The most urgent need in the training of a research scientist is a broad understanding of physical phenomena. This cannot be filled by a prescribed course or curriculum, and only the teacher who himself possesses a broad understanding can effectively aid the student. A teacher who has such an understanding can point out the similarity between one set of physical phenomena and another, and the likenesses between the methods by which similar problems are solved. For instance, in the study of electrostatic fields, we arrive at equations for equipotentials and flow lines by a solution of the so-called equation of Laplace. This same equation holds for fluid flow, and its solution is equally valid for stream lines and pressure contours. Similar equations and solutions are found for vibrating systems in mechanics and for electrical oscillations in circuits. Acoustical impedance is very similar to electrical impedance. All these concepts may be emphasized to aid the student in obtaining a thorough understanding.

There are many other things which can be done to help train our engineers for positions in research and development. Each of us can think of items which might be useful, such as an undergraduate thesis, more mathematics, courses in instrumentation, courses in report writing, etc. However, these suggestions, like all others, rest on personal opinion. As said previously, the one important thing is that we do not actually know what training will make a good research engineer because we have never been able to make any measurements. We have never measured qualifications of a good scientist. What we, as teachers, need more than anything else is research on teaching and, in particular, research on training for research.

Conference on Administration of Research

A conference on the administration of research was held at the Pennsylvania State College, October 6 and 7, 1947. The conference was sponsored by the School of Engineering of the Pennsylvania State College. Two hundred leaders of research management from laboratories in the United States and Canada registered for the conference. Laboratories both large and small, managed by industry, educational institutions and governmental agencies were represented. The high level of ability, reputation and experience in research as represented by the registrants, as well as by those on the program, assured the success of this conference before it was opened.

Following registration, the Monday morning meeting was called to order by H. P. Hammond, Dean of the School of Engineering of the Pennsylvania State College, who, after a brief introductory talk, introduced J. A. Hutcheson, Associate Director of the Research Laboratories of Westinghouse Electric Corporation, as chairman of the Monday morning session. Speakers at this session were Maurice Holland, Industrial Research Adviser, New York City; R. L. Jones, Vice President, Bell Telephone Laboratories; and G. H. Young, Assistant Director, Mellon Institute of Industrial Research.

Mr. Holland spoke on "The Place of Research in the Corporate Structure." The subject of the talk by Dr. Jones was "Organization by Scientific Division." This was followed by a paper "Organization by Individual Projects" by Dr. Young.

The meeting Monday afternoon was led by Philip M. Morse as chairman. Dr. Morse is the Director of Brookhaven National Laboratories. "Research Reports—Their Form and Usefulness" was the subject of a paper by Dwight E. Gray, Editor, Applied Physics Laboratory, Johns Hopkins University. L. W. Chubb, Director of the Research Laboratories of Westinghouse Electric Corporation, presented a paper "Inventions and Patent Policy." "Policy on Publications" was the subject of a talk by E. U. Condon, Director, National Bureau of Standards.

The dinner speaker at the meeting Monday evening was Col. Leslie E. Simon, Director, Ballistic Research Laboratories, Aberdeen Proving Ground, who spoke on "German Research in World War II," based upon personal investigation of German research laboratories made since the war.

The chairman of the session Tuesday morning was J. E. Hobson, Director, Armour Research Foundation. The first paper on the program at this meeting was one by Commodore Henry A. Schade, Director, Naval Research Laboratory, on "Inception and Development of a Research Project." B. B. Wescott, Gulf Research and Development Company, presented a paper, "Analyses of Research Costs." P. D. Foote, Executive Vice-President, Gulf Research and Development Company, used Dr. Wescott's presentation as a basis for a further discussion of "Analyses of Research Costs." "Selection and Training of Research Personnel" was the subject of a paper by A. W. Hull, Assistant Director, Research Laboratories, General Electric Company.

Proceedings of this conference will be published as soon as possible. The price is $3. Copies may be obtained from Prof. Kenneth L. Holderman, Pennsylvania State College, State College, Pennsylvania.

Sections and Branches

The **Allegheny Section** met at State College, October 10, 1947, and the following officers were elected:

Chairman, W. A. Koehler, West Virginia University.
Vice Chairman, R. C. Gorham, University of Pittsburgh.
Secretary, D. T. Worrell, West Virginia University.

The **Kansas-Nebraska Section** held a meeting at the Kansas State College October 17–18, 1947, and elected the following officers:

Chairman, H. L. Daasch, University of Kansas.
Vice Chairman, J. S. Blackman, University of Nebraska.
Secretary-Treasurer, R. F. Morse, Kansas State College.
Representative on Council (2 years), L. E. Conrad, Kansas State College.

The **Missouri Section** has elected S. H. Van Wambeck, Washington University, St. Louis, Mo., as its representative on the General Council for two years.

The **New England Section** elected the following officers at its meeting at the University of Massachusetts, October 11:

Chairman, C. E. Tucker, Massachusetts Institute of Technology.
Secretary, W. E. Keith, New England Tel. & Tel. Co.
Representative on Council (2 years), W. C. White, Northeastern University.

The fall meeting of the **New England Section** of the Society was held at the University of Massachusetts, Amherst, on Saturday, October 11, 1947. The total registration was 307 members and guests.

The following conferences were held:

A. Chemical Engineering

Graduate Study in Chemical Engineering. Walter G. Whitman, Massachusetts Institute of Technology.

B. Civil Engineering

Construction Courses in an Undergraduate Civil Engineering Curriculum. John B. Babcock, Massachusetts Institute of Technology; C. Clark Macomber, Macomber Construction Company, Boston, Massachusetts.

C. Electrical Engineering

English a Neglected Engineering Tool. Donald B. Sinclair, General Radio Company, Cambridge, Massachusetts.

Communications. Lynwood S. Bryant, Massachusetts Institute of Technology.

D. Mechanical Engineering

Specifications for an Engineering Instructor. William H. Kenerson, Brown University; Paul Cloke, University of Maine.

E. Drawing

Secondary School Preparation for College Engineering Drawing. Chester L. Thorndike, Springfield Junior College and Technical High School.

College Graphics Re-examined. C. Harold Berry, Harvard University.

F. Engineering School Libraries

The Engineering Library in Engineering Teaching. Harold Hazen, Massachusetts Institute of Technology.

G. English and Humanities

Reaching the General Reader. Dudley H. Cloud, Managing Editor, *Atlantic Monthly.*

Contemporary Poetry for the Professional Student. John Ciardi, Harvard University.

The Columbia Humanities Program and the Professional Student. Kent Hieatt, Columbia University.

H. Mathematics

Mathematics and Modern Industry. Charles V. L. Smith, Raytheon Manufacturing Company, Waltham, Mass.

A Specification for the Quality Control Engineering Applicant. C. D. Ferris, General Electric Company, Bridgeport, Conn.

I. Mechanics, Strength of Materials, and Fluid Mechanics

What Is Ahead in the Teaching of Fluid Mechanics? Paul E. Hemke, Rensselaer Polytechnic Institute.

What Is Ahead in Strength of Materials Laboratory? Gleason H. MacCullough, Worcester Polytechnic Institute.

J. Physics

Cornell's Program in Engineering Physics. L. P. Smith.

Harvard University's Program in Engineering Sciences and Applied Physics. F. V. Hunt.

What Should the Engineering Student Bring from His Course in Physics? J. P. DenHartog, Massachusetts Institute of Technology; D. E. Howes, Worcester Polytechnic Institute; William P. Kimball, Dartmouth College.

A brief business meeting was held at 1:30 P.M. in Bowker Auditorium with Chairman Tucker presiding. The secretary commented upon the generous response of institutions in the Section to the request for a ten-dollar donation from each to cover printing costs of the News Bulletin and Program, mailing expenses, etc.

J. S. Thompson, Treasurer of the Society, was introduced and brought the greetings of the National Office to the Section. Chairman Tucker read a letter announcing the appointment of Arthur B. Bronwell of Northwestern University as Secretary to replace Dr. F. L. Bishop of the University of Pittsburgh who retired from the office after many years of service. Professor Higbie Young of Cooper Union, and Chairman of the Mid-Atlantic Section of A.S.E.E., spoke briefly and brought the greetings of his Section to the New England Section. Professor C. L. Dawes, the Section's Representative on the National Council, reported briefly upon the recent meeting in Minnesota.

The annual dinner was held at 6:30 P.M. in Greenough Hall with an attendance of 202. Chairman Tucker presided over a brief business meeting following the dinner. Dean L. E. Seeley of the University of New Hampshire, as Chairman of the Nominating Committee, presented the following nominations for officers of the Section for the ensuing year. For Chairman—Professor C. E. Tucker, for Secretary—Mr. W. E. Keith, for Section Representative on the National Council—Dean W. C. White. No additional nominations were presented and with President Dodge presiding

temporarily the nominated officers were elected.

The **North-Midwest Section** elected the following officer at its meeting at Marquette University, October 17–18, 1947:

Chairman, F. L. Partlo, Michigan College of M. & T.

T. C. Brown has been elected to serve as Chairman of the **North Carolina State College Branch,** W. N. Hicks is Vice Chairman.

College Notes

Northwestern Technological Institute. Philip C. Rutledge, Professor of Civil Engineering, was appointed chairman of the department this fall to fill the vacancy caused by Professor George Maney's death. Professor Rutledge has been on the faculty at Northwestern since 1943 and taught at Purdue previously.

New men on the faculty include William T. Brazelton, Instructor, and George Thodos, Assistant Professor of Chemical Engineering; James J. Cadwell, Assistant Professor of Civil Engineering; Messrs. E. Richard Owen and Richard L. Petritz, Instructors in Electrical Engineering, and Messrs. Richard H. Cole and Donald R. Diggs, Lecturer and Instructor in Mechanical Engineering, respectively.

A new nuclear chemistry laboratory is now being equipped by **Rensselaer Polytechnic Institute** to augment its nuclear science and engineering program. Facilities will be provided by the new laboratory for training and research in connection with the course in nuclear chemistry inaugurated by Rensselaer in September. This course is under the direction of H. M. Clark, Assistant Professor of Physical Chemistry.

Papers given last June in Minneapolis before the **Engineering College Research Council** and at the Fifth General Session of the Society have been published in the Proceedings of the Research Council. Copies are available from Mr. John I. Mattill, Secretary, at the State University of Iowa, for $1 each.

James S. Thompson, Treasurer of the A.S.E.E. and Executive Chairman of the Board, McGraw-Hill Book Company, has been appointed a representative of the Committee on International Relations of the **Engineers Joint Council** to attend a meeting of representatives of engineering groups of North and South America at Lima, Peru, to be held the end of November 1947. At the Lima meeting, plans will be made for the organization and the convening of a Pan-American Engineering Congress.